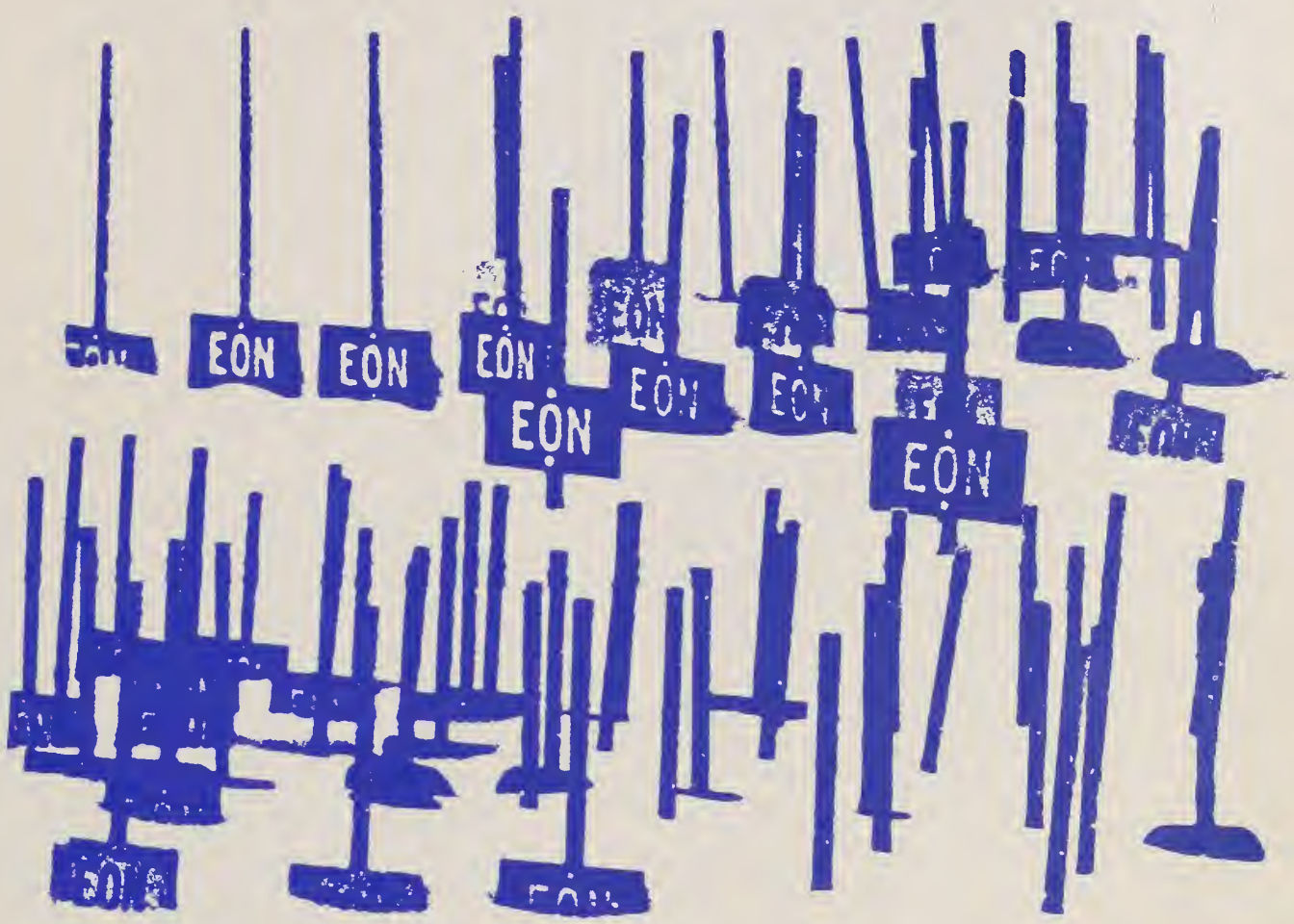
United States
Department of
Agriculture

Forest Service

**Equipment
Development
Center**

Missoula, Mont.

Outdoor Testing of Reflective Sign Materials



U.S. Department
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**Federal Highway
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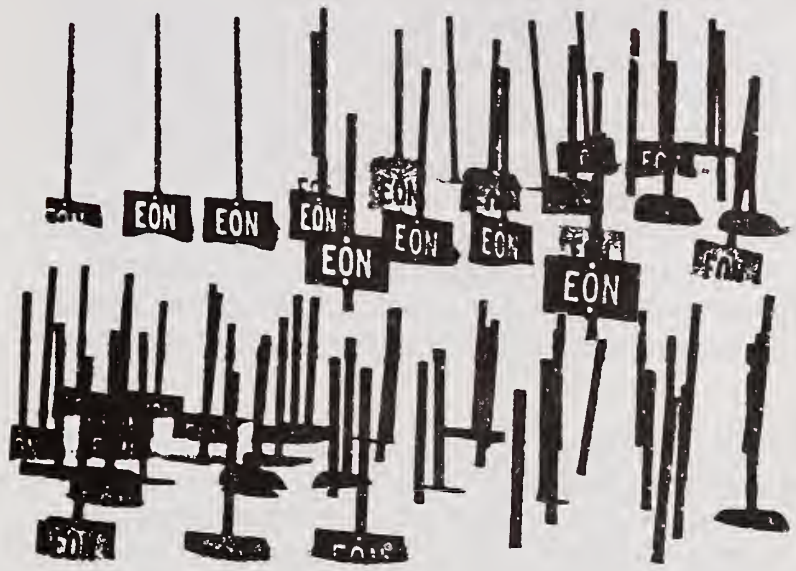
Outdoor Testing of Reflective Sign Materials



TE02L22
Technical Services, Forest Roads & Trails

By
Thomas J. Nettleton
Project Leader

Screen 1 of 2
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Screen 2 of 2

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 15 500      Shipping list no.: 85-1067-P.
 16 500      "TE02L22."
 17 500      "7200-Engineering 8372 2206"--Cover.
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 19 650  0   Signs and signboards ǂx Testing.
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Abstract

Some reflective signs on National Forest land are subjected to extreme temperatures and snow burial. Field units noted the reflective sheeting peeling from these signs after only one winter. In 1972 the Missoula Equipment Development Center (MEDC) began testing outdoor signs of various substrates, reflective sheeting, application techniques, and clear coatings. The goal was to find the right combination of materials and manufacturing processes to produce a reflective sign that would remain maintenance-free for 7 years.

The 3M Co. agreed to take part in the testing. In 1976 two other sheeting manufacturers, Avery International and Mitsubishi/Seibu International, joined the testing, and in 1979 Reflexite Corp. and Carsonite International began participating.

To date, outdoor testing has identified a number of combinations of substrate, reflective sheeting, application techniques, edge seal, and clear coatings that will extend the service life of outdoor reflective signs. These test findings are documented and the specific combinations recommended for manufacturing Forest Service signs are explained in detail.

A report on Technological Improvements Project TE02L22, Technical Services, Forest Roads & Trails, funded by the Engineering Staff.

Acknowledgments

The author wishes to thank the following for their cooperation and participation in the testing of reflective sign materials: 3M Co., Mitsubishi/ Seibu International, Avery International, Reflexite Corp., Carsonite International, Ojo Caliente Craftsmen, Inc., National Institute of Transportation Engineers, American Plywood Association, Benjamin Moore Co., Par Marketing, Finnish Plywood Association USA, Federal Highway Administration, Bureau of Land Management, Simi Fastening Systems, the Tufnut Works, General Services Administration, San Bernardino County, California, and traffic engineering departments and laboratories from Arizona, Washington, Oregon, California, and New Mexico.

Special thanks to Forest Service Regional, Forest, and District personnel of the Southwestern, Pacific Southwest, and Pacific Northwest Regions for providing test sites and installing and monitoring test signs, regardless of weather.

Contents

Reflective signs have been installed on National Forest land to conform with the *Manual on Uniform Traffic Control Devices* and the Highway Safety Act of 1966. When installation began on a broad scale, field units noted the reflective sheeting peeling along the edges of signs after as little as one winter. This deterioration appeared to be more common at higher elevations, but also occurred at lower sites when signs were subjected to extreme temperature change, snow burial, ultraviolet rays, or all three.

Investigation by the Missoula Equipment Development Center (MEDC) revealed that snow burials, extreme temperature change, and ultraviolet rays combine to destroy reflective signing in three basic ways:

1. Peeling of the legend (message) from the background sheeting.

2. Peeling of the reflective sheeting from the substrate (base material).

3. Separating (delaminating) of the layers that make up the reflective sheeting and legend. The first evidence of this type of failure is crazing of the reflective material — minute cracks that cause peeling or delamination if cracks become large enough[1]

It was important to find a solution to the deterioration for two reasons:

- Reflectorized signs were adopted to increase traffic safety, because they communicate clearly to a driver day or night; peeling and delamination destroy the reflectorized sheeting, making the sign less effective.

- Reflectorized signs are expensive — about $12 a square foot on the average — and maintenance or replacement due to premature failures is extremely costly.

MEDC began a project in 1972 to outdoor test signs manufactured of various combinations of substrates, reflective sheeting materials, application techniques, and clear coatings. The goal was to find the right combination of materials and manufacturing techniques to give Forest Service units a rugged reflective sign that could remain in service 7 years without maintenance.

The Forest Service was not the only agency experiencing problems with reflectorized signs. The Federal Highway Administration, Bureau of Land Management, National Park Service, Federal Prison Industries, Inc., and various transportation departments at the State and county level were concerned and asked to participate as observers in the outdoor tests. The American Plywood Association was also interested in the tests and asked to participate.

The 3M Co., manufacturer of much reflective sheeting in Forest Service signs, agreed to take an active part in the testing; and an agreement was entered into regarding the responsibilities of both the Forest Service and 3M. In 1976 two other major reflective sheeting manufacturers, Avery International, and Mitsubishi/Seibu International, entered into similar cooperative agreements to test samples of their reflective materials.

In 1977 a cooperative agreement was also completed with Finnish Plywood Association USA to evaluate the durability of the products of the three sheeting manufacturers on Finnish birch plywood overlayed with phenolic resin. Reflexite Corp. and Carsonite International, a manufacturer of flexible signposts, joined the testing in 1979. Simi Fastening Systems and the Tufnut Works provided vandal-resistant hardware.

Three or four other signpost manufacturers have asked to participate in future tests. Test plots are being established for their products.

Since this report was first printed in 1979, the testing of reflective sheeting has expanded with the addition of many new materials. As a result, this report has been expanded to include the growing list of materials and updated with findings from the latest evaluation, which took place in July 1982.

This revised report is divided into seven parts. Part I describes in detail test objectives and the test methods used to evaluate the reflective materials undergoing outdoor weathering. Parts II through V are separate discussions of each sheeting manufacturer's material. Each part contains recommendations for manufacturing outdoor reflective signs of specific combinations of a firm's materials and processes to achieve maximum service life and durability.

[1]Initial work on the causes of peeling and delamination of reflective signs is documented in MEDC Project Record *Evaluation of 3M Sign Products*, April 1972, 8 p.

Part VI discusses the initial testing of reflectorized delineator posts manufactured by Carsonite International. These posts have been under controlled evaluation for 1 to 3 years, so no conclusions or recommendations about their performance are made. Part VII discusses the vandal-resistant hardware used at the test sites since 1978.

Test Objective

The objective is to test and evaluate as many different materials combinations as practical with accepted manufacturing processes, to provide information needed to produce a durable sign that will remain in service for 7 years without maintenance.

Test Plan

In the fall of 1972, 3M Co. representatives and MEDC personnel met to design a cooperative test plan. At this meeting, guidelines for selecting sign materials, manufacturing processes, and testing methods were agreed upon. In subsequent years test plans identical to the 3M Co. plan were drawn up with Avery International, Mitsubishi/Seibu International, Finnish Plywood Association, USA, Reflexite Corp., and Carsonite International.

Test sites were selected based on snowfall, extreme temperature change, and exposure to ultraviolet rays. Sites chosen were Hopewell Lake, N. Mex. — elevation, 10,000 feet; Donner Summit, Calif. — elevation 7,000 feet; Mount Adams, Wash. — elevation 4,600 feet.

It was agreed that test signs would be produced by an impartial independent contractor. The manufacturer would negotiate a contract with the sign maker, provide all materials, and pay manufacturing costs. It was important that the sign contractor be willing to have company and MEDC representatives monitor the entire manufacturing process and provide technical advice. Ojo Caliente Craftsmen Cooperative, Ojo Caliente, N. Mex., was selected to produce the signs. This firm had worked closely with the Forest Service on other sign testing projects.

To simulate the legend (message), the letters "E," "O," and "N" were selected because they represented the geometrical shapes found in the alphabet.

Evaluation of Test Signs

The Forest Service and sheeting manufacturers agreed on this system for evaluating signs:

- E — Excellent to good durability with no structural failures that would require maintenance (fig. 1).

- L — Legible; sign message legible but maintenance would be required for esthetic purposes and to prevent deterioration (fig. 2).

Figure 1.—Test sign shows no structural failure that would require maintenance.

Figure 2.—Test sign message is legible but maintenance would be required for esthetic purposes and to prevent further deterioration.

• NL — Not Legible; message unreadable, requiring immediate replacement or complete repair (fig. 3).

Figure 3.—Test sign message is becoming unreadable and sign requires immediate replacement or repair.

These definitions of sign failure also were agreed to:

• **Peeling** — Results when sheeting peels from the substrate; in the case of sign legend (message), when letters peel from background sheeting.

Delamination — Separation within the reflective sheeting.

Crazing — Fine cracks within the reflective sheeting. If cracks become large enough to break surface coating, peeling or delamination results.

Evaluations were to be performed as early as possible each spring by technical representatives from the manufacturer and MEDC. Each sample would be photographed and evaluated; any differences of opinion would be settled at the test site, with MEDC reserving the right to make the final recommendation for reporting purposes. Signs that failed and would provide no further information would be removed from the test by MEDC.

Minimum criteria for a sign combination to be considered successful were agreed upon: five of the six signs in the combination (two signs installed at each test site) would have to be rated "E" and the remaining one rated at least "L."

In 1982 the sign evaluation system was expanded to include reflectivity — a measure of a sign's nighttime legibility. It was realized that as sign life increased through better materials and application techniques, sign reflectivity, too, must be maintained. A major loss in reflectivity would make a sign as useless as if it had peeled or delaminated.

For this reason, readings of reflectivity began to be recorded during the latest evaluation, in July 1982. It was agreed between the Forest Service and manufacturers to use FP 79, the national standard specification for new reflective materials used with roads and bridges. This means that *new* reflective sheeting should meet specific intensity readings per unit area as shown in the FP 79 tables. This intensity is expressed in candelas per foot candle per square foot of reflective sheeting. Readings of reflectivity would be taken with a Gamma Scientific Co. retroreflectometer, model 910 with annular ring. To date, minimum reflectivity readings that reflective sheeting must meet or be replaced have not been adopted.

Test Sign Materials and Manufacturing

3M and MEDC selected 50 different combinations of background sheeting, application techniques, top edge treatments, and clear coatings for initial testing. Aluminum and HDO (high-density overlay) plywood, the two basic sign substrates, were used for test signs.

The 3M Co. reflective background sheeting was engineering-grade brown with heat-activated adhesive; high-intensity green with heat-activated adhesive; engineering-grade brown with pressure-sensitive adhesive; high-intensity green with pressure-sensitive adhesive. Letters were high-intensity silver with heat-activated adhesive; engineering-grade silver with pressure-sensitive adhesive; and Control-Tac engineering-grade silver. Some letters were silk screened on the reflective sheeting.

Some 300 test signs were manufactured in October 1972, using these 50 different materials combinations and application techniques (tables 1-3). One hundred signs were installed at the California and Washington test sites in December 1972. Severe weather delayed the installation of the last 100 signs at the Hopewell Lake, N. Mex., site until April 1973.

All test signs measured 8 by 14 inches. They were installed 18 to 24 inches above ground on wood posts then transferred later to steel U-channel posts set in rows (fig. 4). Signs faced south for maximum ultraviolet exposure in summer.

In the fall of 1974 seven new sign combinations of HDO and MDO (medium density overlay) plywood and ABS (acrylonitrile butadiene styrene) plastic substrates were manufactured and installed at each test site (table 4). The MDO

Table 1.—*Reflective signs of 3M Co. materials on aluminum substrate, placed at test sites, 1972-73*

Sign No.	Reflective Materials		Edge Treatment				Clear Coatings				Heat Application	
	Legend[1]	Sheeting[1]	Corners and edges square	#639 film[2]	#700 clear[3]	#800 clear[3]	#700 legend only[3]	#800 legend only[3]	#700 complete sign[3]	#800 complete sign[3]	Normal application	Double cycles
1F1	2270	2279	x									x
1F2	2270	2279	x	x			x					x
1F3	3270	2279	x						x		x	
1F4	3270	3279	x				x				x	
1F5	9270	3279	x	x							x	
1F6	9270	3279	x						x		x	
1F7	Silk screen	3870	x								x	
1F8	3870	2877	x	x							x	
1F9	2870	2877	x			x				x		x
1F10	2870	3877	x				x				x	
1F11	Silk screen	3870	x	x							x	
1F12	3870	3877	x			x				x	x	
1F13	2270	2279	x		x							x
1F14	2270	3270	x		x		x				x	
1F15	3870	3877	x								x	
1F16	3870	3877	x		x			x			x	

Note: • Numbers refer to 3M Co. product numbers.
• Background sheeting placed ½ inch below top edge of sign on Nos. 13, 14, 15, 16.

[1]The following reflective materials were used for letters and sheeting:

2270 = heat-activated, engineering-grade silver;
2279 = heat-activated, engineering-grade brown;
2870 = heat-activated, high-intensity silver;
2877 = heat-activated, high-intensity green;
3270 = pressure-sensitive, engineering-grade, silver;
3279 = pressure-sensitive, engineering-grade brown;
3870 = pressure-sensitive, high-intensity silver;
3877 = pressure-sensitive, high-intensity green;
9270 = Control-Tac engineering-grade silver.

[2]Scotchcal brand transparent film (#639) placed along top edge of sign for added protection against delamination; on signs 1F14 and 1F16, film placed on all edges.

[3]Scotchlite brand process color, #700 series used as clears and edge sealers for engineering-grade sheeting; #800 series used as clears and edge sealers for high-intensity sheeting.

Table 2.—*Reflective signs of 3M Co. (high-intensity sheeting) on HDO plywood substrate, placed at test sites, 1972-73*

Sign No.	Reflective Materials		Edge Treatment					Clear Coatings			Heat Application
	Legend[1]	Sheeting[1]	Corners and edges square	Corners and edges rounded	#639 film[2]	#4150[3] clear	Paint	#800 legend only	#830 complete sign	#831 complete sign	Normal
2F1	3870	2877	x								x
2F2	3870	2877	x		x			x			x
2F3	Silk screen	2877	x			x					x
2F4	2870	2877	x					x	x		x
2F5	Silk screen	2877		x							x
2F6	2870	2877		x		x		x			x
2F7	2870	2877		x					x		x
2F8	3870	3877	x					x			
2F9	3870	3877	x		x						
2F10	3870	3877	x			x		x			
2F11	2870	3877	x							x	
2F12	2870	3877		x				x			x
2F13	2870	3877		x		x					x
2F14	2870	3877		x				x		x	x
2F15	2870	3877		x			x				x
2F16	3870	2877		x			x	x			x

Note: • Numbers refer to 3M Co. product numbers.
• 2F15 — All edges and backs received one coat of brown long oil primer and one coat of Benjamin Moore Co.'s polysilicone enamel (brown) before sheeting and second coat of enamel after sheeting.
• 2F16 — All edges and back received one coat of short oil primer and one coat of Benjamin Moore Co.'s polysilicone enamel (brown) before sheeting and second coat of enamel after sheeting.

[1]2870 = heat-activated, high-intensity silver;
2877 = heat-activated, high-intensity green;
3870 = pressure-sensitive, high-intensity silver;
3877 = pressure-sensitive, high-intensity green.
[2]Scotchcal brand transparent film (#639) placed along top edge of signs for added protection against delamination.
[3]Scotchlite brand process color #4150 series clears used as edge treatment for high-intensity sheeting.

Figure 4.—3M Co. reflective signs undergoing outdoor exposure testing at Hopewell Lake, N. Mex., test site.

plywood and ABS substrates were selected to provide the Forest Service with weathering data on additional substrates and manufacturing alternatives. One combination (4F3) had one letter coated with verathane; two combinations (4F6 and 4F7) had the top edge protected with two types of aluminum extrusions that were screwed to the sign. Sheeting for all combinations were applied with only a single cycle through the heat vacuum applicator, to determine the protective qualities of the verathane and the aluminum edging. The legend on all except 4F2 was hand applied.

In September 1977 12 new sign combinations using aluminum and HDO plywood were installed at the test sites to evaluate two new films (SJ8582X and SJ8583X) designed specifically to protect the top edge of a sign (table 5). Because the interest was in the bond between the substrate and the sheeting, no legends were put on the signs.

Table 3.—*Reflective signs of 3M Co. materials (engineering-grade sheeting) on HDO plywood substrate, placed at test sites, 1972-73*

Sign No.	Reflective Materials		Edge Treatment					Clear Coatings		Heat Application	
	Legend[1]	Sheeting[1]	Corners and edges square	Corners and edges rounded	#639 film[2]	#700 clear	Painted[3]	#700 legend only	#700 complete sign	Normal application	Double cycle
3F1	2270	2279	x				x				x
3F2	2270	2279	x		x			x			x
3F3	2270	2279	x			x					x
3F4	3270	2279	x					x	x	x	
3F5	3270	2279	x				x			x	
3F6	3270	2279		x				x		x	
3F7	9270	2279		x		x		x		x	
3F8	9270	2279		x					x	x	
3F9	9270	2279		x			x	x			x
3F10	2270	3279	x				x				x
3F11	2270	3279	x		x			x			x
3F12	2270	3279	x			x				x	
3F13	3270	3279	x			x			x		
3F14	3270	3279	x				x				
3F15	3270	3279		x							
3F16	9270	3279		x		x		x			
3F17	9270	3279		x					x		
3F18	9270	3279		x			x				

Note: Numbers refer to 3M Co. product numbers.

[1]2270 = heat-activated, engineering-grade silver;
2279 = heat-activated, engineering-grade brown;
3270 = pressure-sensitive, engineering-grade silver;
3279 = pressure-sensitive, engineering-grade brown;
9270 = Control-Tac engineering-grade silver.

[2]Scotchcal brand transparent film (#639) placed along top edge of signs for added protection against delamination.

[3]3F1 = Fuller Co. long oil base prime, one coat (4 ± ½ mil); then four coats Fuller oil base paint applied to edges and back of finished sign.
3F5 = Same as 3F1 except Benjamin Moore Co. short oil prime.
3F9 = Same as 3F1 except primer and two coats of paint before sheeting application; two coats after.
3F10 = Fuller Co. long oil base prime (one coat) and Benjamin Moore Co. polysilicone enamel (brown) (4½ ± ½ mil); four coats applied to edges and back of finished sign.
3F14 = Benjamin Moore Co. short oil base prime (one coat) and polysilicone enamel (brown) (4½ ± ½ mil); four coats applied to edges and back of finished sign.
3F18 = Benjamin Moore Co. short oil base prime (one coat) and Fuller oil base paint (two coats) before sheeting application; two coats after sheeting application.

Table 4.—*Reflective signs of 3M Co. materials, placed at test sites, 1974*

Sign No.	Reflective Materials		Substrates			Edge Treatments				
	Legend[1]	Sheeting[1]	ABS plastic	MDO plywood	HDO plywood	Corners and edges square	Corners and edges round	Flat aluminum over top	Round aluminum over top	Paint
4F1	3270		x							
4F2	2270		x							
4F3	3270	2279			x		x			x
4F4	3270	2279		x		x				
4F5	3270	2279		x		x				
4F6	3270	2279			x		x	x		
4F7	3270	2279			x		x		x	

Note: Numbers refer to 3M Co. product numbers.

4F3 = Short oil base primer; Fuller oil base paint (4½ ± ½ mil.) on edges and back; one letter coated with Verathane.

4F4 = All edges and back received five coats (4½ mils) of Benjamin Moore Co.'s polysilicone enamel (brown) before reflective materials applied.

4F5 = Same as 4F4 except enamel added after reflective materials applied.

4F6 = Short oil base primer, Fuller oil base paint (4½ ± ½ mil).

4F7 = Same as 4F6 except for difference of aluminum top edge.

Two samples of 4F1, 4F2, 4F3, 4F6, and 4F7 were put at each test site; three samples of 4F4 and 4F5 were put at each site.

[1]2270 = heat-activated, engineering-grade silver;
2279 = heat-activated, engineering-grade brown;
3270 = pressure-sensitive, engineering-grade silver.

Table 5.—*Reflective signs of 3M Co. materials, placed at test sites, 1977*

Sign No.	Reflective Materials Sheeting[1]	Edge Treatment[2] SJ8582X film	SJ8583X film
5F1	2279	x	
5F2	2279	x	
5F3	3279	x	
5F4	3279	x	
5F5	2870	x	
5F6	2870	x	
5F7	2279		x
5F8	2279		x
5F9	3279		x
5F10	3279		x
5F11	2870		x
5F12	2870		x

Note: • All HDO plywood edges and corners rounded and received four coats (4½ ± ½ mil) of Benjamin Moore polysilicone enamel (brown), two coats before sheeting application, two coats after.
• Backs are black HDO plywood unpainted.
• Signs 5F1, 5F3, 5F5, 5F7, 5F9, 5F11 HDO substrate; all others aluminum

[1]2279 = heat-activated, engineering-grade brown;
2870 = heat-activated, high-intensity silver;
3279 = pressure-sensitive, engineering-grade brown.

[2]New development in top edge films (tape). Because of shortage of the new films, two of each were installed at Hopewell Lake, N. Mex., test site and one each at Mount Adams, Wash., and Donner Summit, Calif.

In the spring of 1978, 24 more combinations were installed (table 6). These signs (6F series) continued testing the two top edge treatment films, this time on modified reflective sheeting, some with clear coating and silk-screened legends. These signs represented both single- and double-cycled, heat-activated sheeting.

Four combinations of 3M Co. materials on Finnish plywood were installed in 1977 and 1978 (table 7). Another series of signs (7F), using a prototype reflective sheeting, was installed at the test sites in November 1978 and January 1979 (table 8). These signs included white, engineering-grade reflective sheeting with Scotchcal brand transparent film (#639) top edge treatment over either HDO plywood or aluminum substrates.

In October 1982, 13 new sign combinations (8F series) were installed at the three test sites (table 9). The combinations included a new 3M reflective sheeting product, System 5 high intensity, as well as high-intensity, heat-activated silver white, pressure-sensitive white, and engineering-grade, pressure-sensitive white. Legends were high-intensity, heat-activated yellow, engineering-grade, pressure-sensitive white, and silk-screened. Seven combinations included a top edge treatment with #639 film. No signs were clear coated.

Table 6.—*Reflective signs of 3M Co. materials placed at test site, 1978*

Sign No.	Reflective Materials		Substrate		Edge Treatment		Clear Coating[2]
	Legend[1]	Sheeting[1]	HDO plywood	Aluminum	SJ8582X film	SJ8583X film	#800 legend only
6F1	2870	3877		x			
6F2	2870	3877		x	x		
6F3	2870	3877	x				
6F4	2870	3877	x			x	
6F5	Silk screen	3870		x			x
6F6	Silk screen	2870		x		x	x
6F7	Silk screen	2870	x				x
6F8	Silk screen	2870	x		x		x
6F9	Silk screen	3870		x			x
6F10	Silk screen	3870		x		x	x
6F11	Silk screen	3870	x				x
6F12	Silk screen	3870	x		x		x
6F13	Silk screen	2290		x			
6F14	Silk screen	2290		x	x		
6F15	Silk screen	2290		x			
6F16	Silk screen	2290	x				
6F17	Silk screen	2290	x		x		
6F18	Silk screen	2290	x				
6F19	Silk screen	3290		x			
6F20	Silk screen	3290		x	x		
6F21	Silk screen	3290	x				
6F22	Silk screen	3290	x		x		
6F23	Silk screen	2290A		x			
6F24	Silk screen	2290A		x			

Note: • All HDO plywood edges and corners rounded and received four coats (4½ ± ½ mil) of Benjamin Moore Co.'s polysilicone enamel (brown). Backs are HDO plywood unpainted.
• 6F14, 6F18, 6F24, double cycled through heat vacuum applicator; other signs single cycled.
• Silk screen ink used is Scotchlite red on 6F5 through 6F12; Scotchlite brown on 6F13 through 6F24.

[1]2870 = high-intensity, heat-activated silver white;
3870 = high-intensity, pressure-sensitive silver white;
3877 = high-intensity, pressure-sensitive green;
2290 = heat-activated, engineering-grade white;
2290A = heat-activated, engineering-grade improved adhesive white;
3290 = pressure-sensitive, engineering-grade, white.
[2]Legend covered with Scotchlite brand process color, #800 clear.

Table 7.— *Reflective signs of 3M Co. materials on Finnish plywood (phenolic resin film overlay), placed at Hopewell Lake and Donner Summit, 1977, Mount Adams, 1978*

Sign No.	Reflective Materials		Heat Application	
	Legend[1]	Sheeting[1]	Normal cycle	Double cycle
2C1	2270	2279	x	
2C2	2270	2279		x
2C3	3270	3279		x
2C4	3270	3279		

Note: • 2C1 through 2C3 faces were lightly sanded.
• 2C4 face cleaned with turpentine.

[1]2270 = heat-activated, engineering-grade silver;
2279 = heat-activated, engineering-grade brown;
3270 = pressure-sensitive, engineering-grade silver;
3279 = pressure-sensitive, engineering-grade brown.

Table 8.—*Reflective signs of 3M Co. materials placed at test sites, 1978, 1979*

Sign No.	Reflective Sheeting	Substrate	
		HDO plywood	Aluminum
7F1	Prototype	x	
7F2	Prototype		x

Note: Scotchcal brand transparent film (#639) placed along top edge of sign for added protection against delamination.

Table 9.—*Reflective signs of 3M Co. materials placed at test sites, 1982*

Sign No.	Reflective Materials[1] Legend	Sheeting	Substrate HDO plywood	Aluminum	Edge Treatment #639 film[2]
82F1		System 5 High Intensity	x		
82F2		System 5 High Intensity		x	
82F3		System 5 High Intensity		x	x
82F4	Silk screen	2870	x		
82F5	2871	2870	x		x
82F6	2871	3870	x		
82F7	Silk screen	3870	x		x
82F8	Silk screen	2870	x	x	
82F9	2871	2870		x	x
82F10	Silk screen	3870		x	
82F11	Silk screen	3870		x	x
82F12	3270	2279	x		x
82F13	3270	2279		x	x

[1]2870 = high-intensity, heat-activated silver white;
2871 = high-intensity, heat-activated yellow;
3870 = high-intensity, pressure-sensitive silver white;
2279 = engineering-grade, heat-activated brown;
3270 = engineering-grade, pressure-sensitive white.

[2]Scotchcal brand transparent film placed along top edge of sign for added protection against delamination.

Test Results

The original 50 sign combinations were evaluated in 1974, 1975, 1976, and 1977. By 1977, only six combinations had weathered well enough to meet the minimum criteria of five signs rated "E," with the sixth sign rated at least "L" (fig. 5).

Figure 5.—This sign rated excellent after 6 years of outdoor exposure.

The six combinations were 1F2, 2F13, 3F2, 3F3, 3F10, and 3F11; 3F3 and 3F10 were then eliminated because they largely duplicated 3F2 and 3F11.

1F2 was the only successful combination that had an aluminum substrate (table 1). 2F13 was the only successful combination that had green high-intensity grade sheeting (fig. 6) (table 2). The remaining successful combinations (table 3) had brown engineering-grade sheeting, one with pressure-sensitive adhesives and one with heat-activated adhesives.

3F2 had Scotchcal brand transparent film (#639) on the top edge; the legend had been clear coated. 3F3 had been clear coated on the top edge. Analysis of other combinations indicated that the film was more effective than the clear coat in protecting the top edge of a sign. It was found that placing a coat of clear over heat-activated letters was unnecessary. 3F10 had the top edge simply painted, but this was found to be unsatisfactory in many other combinations.

Figure 6.—This was the only successful sign combination that had green high-intensity grade sheeting.

The manufacturing variables — background sheeting, application techniques, edge seals, top edge treatment, clear coating — used in each of the four combinations were compared to identical variables in failed signs. In no case had these manufacturing variables been the cause of a sign failure.

Five years of outdoor testing also revealed these findings:

- Peeling of background sheeting was generally more severe on aluminum than on plywood (fig. 7). Severe crazing occurred on high-intensity sheeting where clear coating had been applied.

Figure 7.—Background sheeting generally peeled more severely from aluminum than plywood.

• The #639 film taped across the top edge of some test signs for added protection against peeling was deteriorating; it showed the most wear at Hopewell Lake where ultraviolet exposure was greatest. But the film continued to preserve the bond between the sheeting and the substrate. (It proved to have a useful life of 4 to 5 years — 3 years when exposed to large amounts of ultraviolet rays.)

• Placing the top edge of the sheeting down ½ inch from the top on aluminum substrate did not prevent peeling or delamination of the sheeting. Of eight signs made this way for each test site at Mount Adams, six were rated "L" and two were removed; at Hopewell Lake, four were rated "E" and four "L"; three were rated "E" and five "L" at Donner Summit.

• Silk screened legends weathered well. There were no failures.

Of the seven new sign combinations installed in the fall of 1974 (table 4), we found that legends on the ABS plastic substrate had suffered moderate to severe delamination at the Hopewell Lake site; the MDO plywood combinations (except one sample) were rated excellent after 3 years' exposure. The one failure appears to be more a result of the higher ultraviolet ray exposure at this test site. The plywood signs with aluminum over the top edge have not peeled at the top to date.

The samples with verathane over one letter had not failed in peeling, delamination, or crazing, but the letter began turning yellow after 3 years.

Note: Because of changes in reflective sheeting formulations by 3M Co. after the first test report was printed in 1979, testing was discontinued on the 1F, 2F, 3F, and 4F series signs.

At the time of the latest evaluations — July 1982 — the 5F series signs (table 5) had been exposed about 5 years. This series tested two top edge treatment films on the latest high-intensity, engineering-grade reflective sheeting covering both HDO plywood and aluminum substrates. Test results indicated that the SJ8582X treatment film performed well on all signs. The SJ8583X treatment film, on the other hand, failed on all but two signs, the 5F8 and 5F9.

All 5F signs except three showed failures in both delamination and peeling. The exceptions included 5F6, a sign with heat-activated high-intensity sheeting that covered an aluminum substrate; 5F7, a sign with heat-activated engineering-grade sheeting that covered an HDO plywood substrate; and 5F8, a sign with double-cycled, heat-activated sheeting that covered an aluminum substrate.

Signs 5F1, 5F3, 5F4, and 5F5 were removed from test sites because of early failures.

The 6F signs were placed at the test sites in spring 1978 and have been exposed for almost 4 years when last evaluated.

These signs included different combinations of reflective materials, substrates, and top edge treatments. Seven signs in the series showed little failure, or none at all. These were 6F6, 6F11, 6F12, 6F14, 6F17, 6F20, and 6F22. Every 6F sign except 6F11 contained a top edge treatment film.

Three of the eight signs with #800 clear coating on high-intensity sheeting survived without failures. These included 6F6, a sign with single-cycled, heat-activated, high-intensity sheeting on an aluminum substrate; 6F11, a sign with single-cycled, heat-activated, high-intensity sheeting on an HDO plywood substrate; and 6F12, a sign like 6F11 except that it included a top edge treatment film. Sign 6F14 used aluminum substrate and reflective sheeting with heat-activated adhesive, double-cycled through the heat vacuum applicator. Top edges were sealed with protective film. Sign 6F17 used an HDO plywood substrate and pressure-sensitive adhesive cycled once through the vacuum applicator. Signs 6F20 and 6F22 included an aluminum substrate and reflective sheeting with single-cycled, pressure-sensitive adhesive. Both these signs included protective edge treatment film.

The 2C series signs had been exposed for almost 4 years when last evaluated. The 2C series tested the compatibility of Finnish plywood and 3M reflective sheeting. All 2C signs showed severe delamination and peeling of both the sheeting background and legend. Furthermore, 2C signs were severely damaged by rodents at all test sites. We suspect that additional adhesive used in 2C signs attracted these animals.

The 7F series signs had been exposed at the test sites for about 3½ years when evaluated for this report.

All 7F signs included white, engineering-grade reflective sheeting with top edge treatment films (#639) that covered either HDO plywood or aluminum substrates. 7F signs with HDO plywood substrate showed no failure. 7F signs with aluminum substrates showed some peeling and delamination. The top edge treatment film had cracked, but did not peel, on all 7F signs.

The 8F series signs (table 9) have not undergone enough exposure to evaluate their durability.

Reflectivity became part of the test sign evaluation procedure in 1982. Reflectivity readings were taken randomly by Forest Service and industry personnel at each test site. Several readings of each color of reflective sheeting were taken, including those with silk-screened inks. All readings for a given type of sheeting were then averaged. Reflective sheeting materials all registered well above the FP 79 minimum standard except for those using silk-screen inks (table 10).

Table 10.— *Average reflectivity readings for 3M Co. products — October 1982*

Reflective Sheeting	Candelas/ ft candle/ sq ft	FP 79 Standard[1] (candelas/ ft candle/sq ft)
Engineering-grade brown	4.48	1.0
Engineering-grade brown (silk screened)	0.0	1.0
Engineering-grade white	85.25	70.0
High-intensity green	50.45	30.0
High-intensity red	16.3	35.0
(silk screened)		
High-intensity white	288.9	250.0
New engineering-grade white (7F signs placed in January 1979)	115.3	70.0

Note: Readings were taken using a retroreflectometer, Model 910, manufactured by the Gamma Scientific Co. The instrument includes an annular ring, factory installed and calibrated on September 15, 1981.

[1]These minimums are for new products; we have not established a minimum reflectivity for replacement sheeting. FP 79 is the national standard specification for road and bridge construction.

Discussion

Test findings indicate that the service life of reflective signs can be extended, using specific combinations of materials and manufacturing processes.

Based on 3 to 5 years of experience, the test procedure adopted appears to be effective in isolating premature failures. Its primary value is in testing products under real-use conditions, which cannot be simulated in the laboratory with today's technology.

In addition to rating each sign, careful examination was made of other features and notes were taken to document findings. Failures were examined in an attempt to correlate them with the unique materials combinations and manufacturing process.

One observation was that the life of plywood veneers is extended by using plywood substrates with rounded edges and painting them with polysilicone paint; the paint does not protect the top edge of reflective sheeting, however.

Another observation was that few of the edge seals had prevented moisture from entering the plywood.

From these observations, and from observing signs produced according to Southwestern Region specifications, it can be shown that two coats of Benjamin Moore polysilicone paint without any primer will protect plywood edges from moisture for more than 4 years. The edges must also be rounded to help reduce the stresses in the paint film.

The Finnish plywood, although durable, proved to be extremely attractive to rodents at all sites, resulting in loss of the signs (fig. 8).

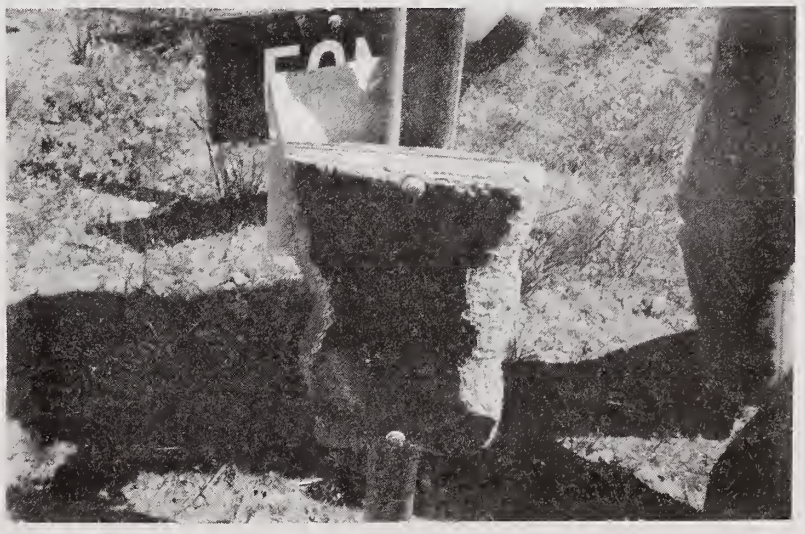

Figure 8.—Signs of Finnish plywood were heavily damaged by rodents.

Conclusions

1. Specific combinations of substrates, reflective sheeting, top edge treatments, application techniques, and clear coatings are available to substantially increase the service life of reflective signs. Four sign combinations met the desired criteria and should have a service life comparable to test goals.

2. Bonding the sheeting ½ inch below the top of aluminum sheeting does not improve longevity.

3. Improvements are needed before ABS plastics can be adopted for use.

4. An aluminum extrusion placed over the top edge of a sign appears to increase longevity. It is extremely costly and was made a part of the testing only to gain data on a method of sign protection that might be resorted to in the most extreme outdoor conditions when all other sign combinations had failed.

5. The Scotchcal brand transparent film (#639) is durable and can be used effectively but an ultraviolet inhibitor is needed to extend service life to 7 years.

6. Silk screened letters are durable. They can be considered an alternative to letters of reflective sheeting. Sheeting manufacturers' recommendations must be followed when applying the ink.

7. If a verathane coating over letters is not durable, an ultraviolet inhibitor will need to be added to the verathane.

8. Although the bond between paint and sheeting is not adequate, the top edge bond is protected with #639 film.

9. Plywood edges should be rounded and painted to insure that moisture does not get into the sign so that checking and cracking of veneers can be avoided. Benjamin Moore polysilicone paint without primer will protect edges from moisture for more than 5 years.

10. Performance of the 5F, 6F, and 7F series signs to date does not indicate any changes in recommendations made in 1979.

11. MDO plywood shows plywood delamination at all sites with all manufacturers.

12. New Scotchcal brand top edge tapes have been developed and evaluated — #SJ8582X and #SJ8583X — with mixed results. Both have been removed from the market.

Recommendations

The recommendations that follow are based on 3 to 5 years of outdoor testing. Manufacturing and maintenance costs were considered during testing and are reflected in the recommendations. For example, black HDO, which is impervious to moisture is recommended, reducing maintenance costs; the optimal use of group 1 B grade veneers on both sides of the substrate, instead of exterior-marine grade, to lower cost; and the elimination of a special primer for the edge paint.

1. It is recommended that outdoor reflective signs for Forest Sevice use be manufactured with these combinations of materials and processes (they are recommended equally, and their order of presentation has no significance):

Reflective Sign of Aluminum

Substrate: No. 6061-T6 plate stock conforming to ASTM Standard B209.

Background Sheeting: 3M Co.'s engineering-grade brown with heat-activated adhesives (#2279).

Legend: 3M Co.'s engineering-grade silver with heat-activated adhesive (#2270) or silk screened.

Manufacturing Process: (1) Double cycle through heat vacuum applicator. (2) Coat the legend with 3M Co.'s Scotchlite brand process color (#700) clear (follow instructions on container). Clear coating not required for silk-screen legend.

Top Edge Treatment: Apply 3M Co.'s Scotchcal transparent film (#639) over top edge of sign. For adequate protection, 3-inch-wide film is recommended. For ease of handling and cleanliness, it should be applied in 24-inch-long strips. On larger signs, begin taping from each outside edge and tape toward center of sign. Film should overlap at the center of sign 2 or more inches. The purpose of the film is to provide complete protection to the top edge of the sign to help prevent the sheeting from peeling from the substrate.

Reflective Sign of HDO (High-Density Overlay) Plywood and High-Intensity Sheeting

Substrate: HDO front and back. All Douglas-fir, exterior-marine grade, conforming to product standard PSI-74; or all Douglas-fir exterior plywood, PSI-74, group 1, with B grade veneers on both sides. HDO must be a 60-60 nonoiled resin impregnated fiber, black in color. Each panel should be edge-branded, marine-grade HDO EXT PSI-74 or HDO B-B G 1 EXT PS 1-74, 5-ply, ½-inch; or 7-ply, ¾-inch. (Thickness will vary depending on sign size, as defined in the Forest Service procurement and manufacturing specification.)

Background Sheeting: 3M Co.'s high-intensity green with pressure-sensitive adhesive (#3877).

Legend: 3M Co.'s high-intensity silver with heat-activated adhesive (#2870) or silk screened.

Manufacturing Process: (1) Cut plywood blank. (2) Round or bevel edges to a radius of 3/32 inch; round corners. (3) Finish-sand all edges and the panel face (HDO). (4) Clean all surfaces with a tack rag. (5) Before sheeting, apply one coat of Benjamin Moore Co.'s #120-60 polysilicone enamel as a primer to all edges. (6) Apply sheeting to substrate. (7) Apply one more coat of enamel after sheeting has been applied to substrate. (8) Apply legend and cycle once through heat vacuum applicator. Do not apply clears.

Top Edge Treatment: Apply 3M Co.'s Scotchcal transparent film (#639) over top edge of sign. For adequate protection of ¾-inch plywood, 3-inch-wide film is recommended. For ease of handling and cleanliness, apply in 24-inch-long strips. On larger signs, begin taping from each outside edge and tape toward center of sign. Film should overlap at the center of the sign at least 2 inches. The purpose of the film is to provide complete protection to the top edge of the sign to help prevent the sheeting from peeling from the substrate.

Reflective Sign of HDO Plywood and Engineering-Grade Sheeting.

Substrate: HDO front and back. All Douglas-fir, exterior-marine grade, conforming to product standard PSI-74, or all Douglas-fir exterior plywood, PSI-74, group 1, with B grade veneers on both sides. HDO must be a 60-60 nonoiled resin impregnated fiber, black in color. Each panel should be edge-branded, marine-grade HDO EXT PSI-74 or HDO B-B G 1 EXT PS 1-74, 5-ply, ½-inch; or 7-ply, ¾-inch. (Thickness will vary depending on sign size, as defined in the Forest Service procurement and manufacturing specification.)

Background Sheeting: 3M Co.'s engineering-grade brown with heat-activated adhesives (#2279).

Legend: 3M Co.'s engineering-grade silver with heat-activated adhesives (#2270); or 3M Co.'s engineering-grade silver with pressure-sensitive adhesives (#2270); or silk-screened.

Manufacturing Process: (1) Cut plywood blank. (2) Round or bevel edges to a radius of 3/32 inch; round corners. (3) Finish-sand all edges and the panel face (HDO). (4) Clean all surfaces with a tack rage. (5) Before sheeting, apply one coat of Benjamin Moore Co.'s #120-60 polysilicone enamel as a primer to all edges. (6) Apply sheeting to substrate. (7) Apply one more coat of enamel to edges after sheeting has been applied to substrate. (8) Apply legend. If using heat-activated letters, cycle sign twice through the heat vacuum applicator. Do not apply clears. If using pressure-sensitive letters, cycle sheeting through heat vacuum applicator once before applying legend and once after. Do not apply clears.

Top Edge Treatment: Apply 3M Co.'s Scotchcal transparent film (#639) over top edge of sign. For adequate protection of ¾-inch plywood, 3-inch-wide film is recommended. For ease of handling and cleanliness, apply in 24-inch-long strips. On larger signs, begin taping from each outside edge and tape toward center of sign. Film should overlap at the center of the sign at least 2 inches. The purpose of the film is to provide complete protection to the top edge of the sign to help prevent the sheeting from peeling from the substrate.

2. Outdoor testing and evaluation of new sign combinations under cooperative agreements with reflective sheeting manufacturers should continue until project goals are met and to insure that the most desirable combinations for outdoor use are identified as the state-of-the-art advances.

Test Sign Materials and Manufacturing

Since the Forest Service and 3M Co. began their cooperative testing of reflective sign materials 10 years ago, other companies have entered the reflective sheeting field. For this reason, the Forest Service invited these manufacturers to supply reflective materials for testing as 3M was doing. Avery International concluded a cooperative agreement in 1976 with the Forest Service.

A test plan identical to the one agreed to by 3M was adopted, and separate test plots for Avery signs were set up at the existing test sites in California, New Mexico, and Washington. Plots were physically separated from the 3M Co. plots but provided the same exposure to the elements.

Signs of Avery materials were manufactured and installed at the test sites in November 1976. Signs of aluminum and plywood measured 8 by 14 inches; those of ABS plastic, 12 by 12 inches. Signs were installed 18 to 24 inches above ground on steel U-channel posts set in rows. Signs faced south for maximum exposure to ultraviolet rays.

Some 28 different sign combinations (1A-5A series) were produced by Ojo Caliente Craftsmen Cooperative, under MEDC and Avery supervision, with substrates of HDO and MDO plywood, aluminum, and ABS plastic (tables 11-15). Heat-activated and pressure-sensitive engineering-grade white and green reflective sheeting was used. (Avery did not manufacture a brown sheeting until 1979.) The letters "E," "O," and "N" were selected to simulate the legend. Letters were either reflective sheeting or silk screened on the signs. Some edges were square, others were rounded. Scotchcal film (#639) was used as a top edge treatment, and polysilicone paint and various clears were used to seal the edges. Some of the HDO plywood signs were treated with Scotchlite brand process color #700 series clears; others were not, to verify if the adhesives were durable without added protection.

In all, 168 test samples were installed at the three sites in November 1976.

The first evaluation took place in June 1977. After one winter of outdoor exposure, sheeting had peeled on several of the ABS plastic and aluminum substrates.

Table 11.—*Reflective signs of Avery Int'l. materials on aluminum substrate, placed at test sites, 1976*

Sign No.	Reflective Materials		Heat Application	
	Legend[1]	Sheeting[1]	Normal cycle	Double cycle
1A1	1200	1209		x
1A2	1100	1209	x	
1A3	1100	1109		
1A4	1200	1109		x
1A5	Silk screen	1109		
1A6	Silk screen	1200		x

Note: Silk screen ink used is Advance Co. (REX 710).

[1]1100 = pressure-sensitive, engineering-grade white;
1109 = pressure-sensitive, engineering-grade green;
1200 = heat-activated, engineering-grade white;
1209 = heat-activated, engineering-grade green.

Table 12.— *Reflective signs of Avery Int'l. materials on HDO plywood substrate, placed at test sites, 1976*

Sign No.	Reflective Materials		Heat Application	
	Legend[1]	Sheeting[1]	Normal cycle	Double cycle
2A1	1200	1209		x
2A2	1100	1209	x	
2A3	1100	1109		
2A4	1200	1109		x
2A5	Silk screen	1109		
2A6	Silk screen	1200		x

Note: • Numbers refer to Avery product numbers.
• All edges and corners rounded and received four coats (4½ ± ½ mil) of Benjamin Moore Co.'s polysilicone enamel (brown).
• Backs are black HDO plywood unpainted.
• Silk screen ink: Advance (REX 710).

[1]1100 = pressure-sensitive, engineering-grade white;
1109 = pressure-sensitive, engineering-grade green;
1200 = heat-activated, engineering-grade white;
1209 = heat-activated, engineering-grade green.

In the fall of 1977 three combinations of prototype sheeting and letters (6A series) were installed at the three test sites (table 16).

By the spring of 1978 all combinations installed at both the Mount Adams test site and the Donner Summit test site demonstrated some degree of failure (fig. 9). However, at the Hopewell Lake site, only a few of the combinations exhibited any failure. As a result, Avery removed all signs in series 1A through 5A from the test sites.

Table 13.— *Reflective signs of Avery Int'l. materials on MDO plywood substrate, placed at test sites, 1976*

Sign No.	Reflective Materials		Heat Application	
	Legend[1]	Sheeting[1]	Normal cycle	Double cycle
3A1	1200	1209		x
3A2	1100	1209	x	
3A3	1100	1109		
3A4	1200	1109		x
3A5	Silk screen	1109		
3A6	Silk screen	1200		x

Note: • Numbers refer to Avery product numbers.
• All sign corners rounded; all edges and backs received four coats (4½ ± ½ mil) of Benjamin Moore Co.'s polysilicone enamel (brown).
• Backs were unpainted before applying sheeting.
• Silk screen ink: Advance (REX 710).

[1]1100 = pressure-sensitive, engineering-grade white;
1109 = pressure-sensitive, engineering-grade green;
1200 = heat-activated, engineering-grade white;
1209 = heat-activated, engineering-grade green.

Table 14.— *Reflective signs of Avery Int'l. materials on ABS "accurene" brown plastic substrate, placed at test sites, 1976*

Sign No.	Reflective Materials		Heat Application	
	Legend[1]	Sheeting[1]	Normal cycle	Double cycle
4A1	1200	1209		x
4A2	1100	1209	x	
4A3	1100	1109		
4A4	1200	1109		x
4A5	Silk screen	1109		
4A6	Silk screen	1200		x

Note: • Sign corners rounded.
• Silk screen ink: Advance Co. (REX 710).

[1]1100 = pressure-sensitive, engineering-grade white;
1109 = pressure-sensitive, engineering-grade green;
1200 = heat-activated, engineering-grade white;
1209 = heat-activated, engineering-grade green.

Table 15.—*Reflective signs of Avery Int'l. materials on HDO plywood substrate, placed at test sites, 1976*

Sign No.	Reflective Materials		Edge Treatment			Clear Coatings		Heat Application	
	Legend[1]	Sheeting[1]	Corners and edges square	Corners and edges rounded	#639 film[2]	#700 legend only[3]	#700 complete sign[4]	Normal cycle	Double cycle
5A1	1100	1109		x	x				
5A2	1100	1209		x	x			x	
5A3	1200	1209	x				x	x	
5A4	1100	1209		x		x		x	

Note: • Numbers refer to Avery product numbers, unless otherwise indicated.
• All edges received four coats (4½ ± ½ mil) Benjamin Moore Co.'s polysilicone enamel (brown).
• Backs are black HDO unpainted.

[1]1100 = pressure-sensitive, engineering-grade white;
1109 = pressure-sensitive, engineering-grade green;
1200 = heat-activated, engineering-grade white;
1209 = heat-activated, engineering-grade green.

[2]Scotchcal brand transparent film (#639) placed along top edge of signs for added protection against delamination.

[3]Legend only covered with Scotchlite brand process color, #700 clear.

[4]Complete signs covered with Scotchlite brand process color, #700 clear.

Table 16.—*Reflective signs of Avery Int'l. materials on HDO and MDO plywood substrates, placed at test sites, 1977*

Sign No.	Reflective Materials		Substrate			Edge Treatment		Heat Application
	Legend[1]	Sheeting[1]	MDO plywood	HDO plywood	Aluminum	#639 film[2]	Painted	Double cycle
6A1	MR426-2102	CTR-2102		x		x	x	x
6A2	MR426-2102	CTR-2102	x			x	x	x
6A3	MR426-2102	CTR-2102			x			x

Note: • Numbers refer to Avery product numbers, unless otherwise indicated.
• All HDO plywood edges were rounded and received four coats (4½ ± ½ mil) of Benjamin Moore Co.'s polysilicone enamel (brown). Backs are black HDO unpainted.
• All MDO plywood edges were rounded, all edges and backs received four coats (4½ ± ½ mil) of Benjamin Moore Co.'s polysilicone enamel (brown).

[1]MR426-2102, experimental-prototype letters; CTR-2102, experimental-prototype sheeting.

[2]Scotchcal brand transparent film (#639) placed along top edge of sign for added protection against delamination.

Figure.9—Early combination of Avery International materials after 2 years of outdoor exposure.

In response to these failures, the company developed new materials, modified original formulations, including adding ultraviolet ray inhibitors, and added tapes to the top edge of signs. Forty new sign combinations (series 7A-10A) were manufactured and installed in October 1978 (tables 17-20) (fig. 10). In addition, six combinations using Finnish plywood substrates (series 3C) were also manufactured and installed at the same time (table 21).

In 1979, 1980, and 1981, a total of 15 new sign combinations were installed at the three test sites (tables 22-24). These signs included new combinations of the top edge films, new reflective sheeting, and adhesives (fig. 11).

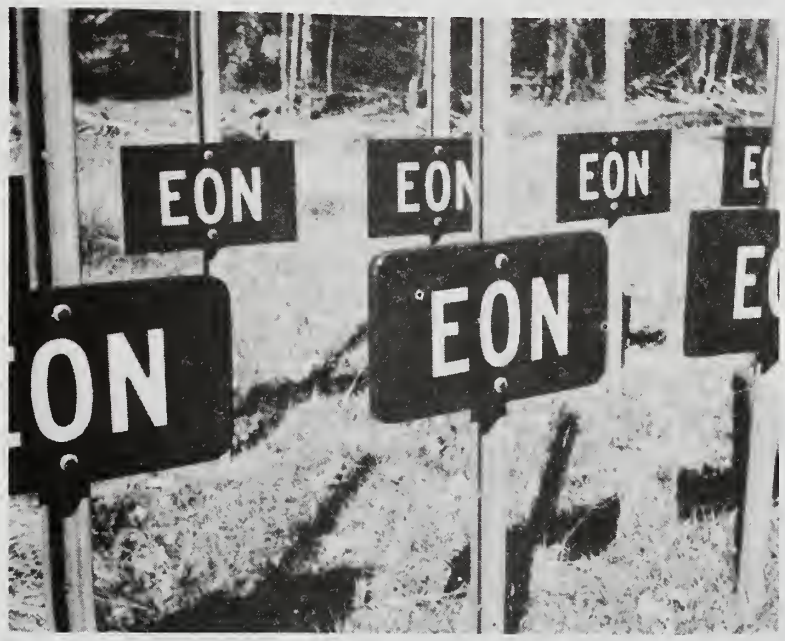

Figure 10.—Avery International sign combinations installed in October 1978.

Figure 11.—Avery International sign combination installed in October 1981.

Table 17.—*Reflective signs of Avery Int'l. materials on aluminum substrate, placed at test sites, 1978*

Sign No.	Reflective Materials		Edge Treatment		Clear Coating		Heat Application
	Legend[1]	Sheeting[1]	#700 film[2]	#900 film[2]	Advance face only[3]	KC face only[3]	Normal cycle
7A1	1200	1207		x	x		x
7A2	1200	HA green prototype		x	x		x
7A3	Silk screen	1200		x	x		x
7A4	Silk screen	HA white prototype		x		x	x
7A5	Silk screen	1200		x		x	x
7A6	Silk screen	HA white prototype		x	x		x
7A7	1200	PS green prototype	x		x		x
7A8	1200	PS green prototype	x		x		x
7A9	Silk screen	PS white prototype	x		x		
7A10	Silk screen	PS white prototype	x			x	
7A11	Silk screen	PS white prototype	x			x	
7A12	Silk screen	PS white prototype	x		x		

[1]HA = heat-activated;
PS = pressure-sensitive;
1200 = heat-activated, engineering-grade white;
1207 = heat-activated, engineering-grade green.

[2]Avery #700 polyester film, top edge only;
Avery #900 vinyl film, top edge only.

[3]Advance Co. transparent clear coat;
KC Co. transparent clear coat.

Note: • Silk screen ink: Advance Co. opaque black on 7A3, 7A9.
• Silk screen ink: Advance Co. transparent red on 7A6, 7A12.
• Silk screen KC Co. transparent black on 7A4, 7A10.
• Silk screen KC Co. transparent red on 7A5, 7A11.
• Only one of each installed at each test site, per Avery International request.

Table 18.—*Reflective signs of Avery Int'l. materials on HDO plywood substrate, placed at test sites, 1978*

Sign No.	Reflective Materials		Edge Treatment		Clear Coating		Heat Application
	Legend[1]	Sheeting[1]	#700 film[2]	#900 film[2]	Advance face only[3]	KC face only[3]	Normal cycle
8A1	1200	1207		x	x		x
8A2	1200	HA green prototype		x	x		x
8A3	Silk screen	1200		x	x		x
8A4	Silk screen	HA white prototype		x		x	x
8A5	Silk screen	1200		x		x	x
8A6	Silk screen	HA white prototype		x	x		x
8A7	1200	PS green prototype	x		x		x
8A8	1200	PS green prototype	x		x		x
8A9	Silk screen	PS white prototype	x		x		
8A10	Silk screen	PS white prototype	x			x	
8A11	Silk screen	PS white prototype	x			x	
8A12	Silk screen	PS white prototype	x		x		

Note: • All edges and corners rounded. All edges received four coats (4 ± ½ mil) Benjamin Moore Co.'s polysilicone enamel (brown) — two coats prior to sheeting application, two coats after. Backs are black HDO unpainted.
• Silk screen ink: Advance Co. opaque black on 8A3, 8A9.
• Silk screen ink: Advance Co. transparent red on 8A6, 8A12.
• Silk screen KC Co. transparent black on 8A4, 8A10.
• Silk screen KC Co. transparent red on 8A5, 8A11.
• Only one of each installed at each test site, per Avery International request.

[1]HA = heat-activated;
PS = pressure-sensitive;
1200 = heat-activated, engineering-grade white;
1207 = heat-activated, engineering-grade green.

[2]Avery #700 polyester film, top edge only;
Avery #900 vinyl film, top edge only.

[3]Advance Co. transparent clear coat;
KC Co. transparent clear coat.

Table 19.—*Reflective signs of Avery Int'l. materials on MDO plywood substrate, placed at test sites, 1978*

Sign No.	Reflective Materials		Edge Treatment		Clear Coating		Heat Application
	Legend[1]	Sheeting[1]	#700 film[2]	#900 film[2]	Advance face only[3]	KC face only[3]	Normal cycle
9A1	1200	1207		x	x		x
9A2	1200	HA green prototype		x	x		x
9A3	Silk screen	1200		x	x		x
9A4	Silk screen	HA white prototype		x		x	x
9A5	Silk screen	1200		x		x	x
9A6	Silk screen	HA white prototype		x	x		x
9A7	1200	PS green prototype	x		x		x
9A8	1200	PS green prototype	x		x		x
9A9	Silk screen	PS white prototype	x		x		
9A10	Silk screen	PS white prototype	x			x	
9A11	Silk screen	PS white prototype	x			x	
9A12	Silk screen	PS white prototype	x		x		

Note: • All edges and corners rounded. All edges and backs received four coats (4 ± ½ mil) Benjamin Moore Co.'s polysilicone enamel (brown) — two coats prior to sheeting application, two coats after.
• Silk screen ink: Advance Co. opaque black on 9A3, 9A9.
• Silk screen ink: Advance Co. transparent red on 9A6, 9A12.
• Silk screen KC Co. transparent black on 9A4, 9A10.
• Silk screen KC Co. transparent red on 9A5, 9A11.
• Only one of each installed at each test site, per Avery International request.

[1]HA = heat-activated;
PS = pressure-sensitive;
1200 = heat-activated, engineering-grade white;
1207 = heat-activated, engineering-grade green.

[2]Avery #700 polyester film, top edge only;
Avery #900 vinyl film, top edge only.

[3]Advance Co. transparent clear coat;
KC Co. transparent clear coat.

Table 20.— *Reflective signs of Avery Int'l. materials on HDO plywood and aluminum substrates, placed at test sites, 1978*

Sign No.	Reflective Materials		Substrate		Edge Treatment
	Legend[1]	Sheeting[1]	HDO plywood	Aluminum	#/ 00 film[2]
10A1	PS green prototype	PS white prototype		x	
10A2	PS green prototype	PS white prototype		x	x
10A3	PS green prototype	PS white prototype	x		
10A4	PS green prototype	PS white prototype	x		x

Note: • All HDO plywood edges and corners rounded. All edges received four coats (4½ ± ½ mil) Benjamin Moore Co.'s polysilicone enamel (brown) — two coats prior to sheeting application, two coats after. Backs are black HDO unpainted. Only one of each installed at each test site, per Avery International request.
• Pressure sensitive with applied legend was cycled through the heat vacuum applicator.

[1]PS = pressure-sensitive.

[2]Avery #900 vinyl film top edge only.

Table 21.—*Reflective signs of Avery Int'l. materials on Finnish plywood (phenolic resin film overlay), placed at test sites, 1978*

Sign No.	Reflective Materials		Edge Treatment	Clear Coating		Heat Application
	Legend[1]	Sheeting[1]	#900 film[2]	Advance face only[3]	KC face only[3]	Normal cycle
3C1	1200	1207	x	x		x
3C2	1200	HA green prototype	x	x		x
3C3	Silk screen	1200	x	x		x
3C4	Silk screen	HA white prototype	x		x	x
3C5	Silk screen	1200	x		x	x
3C6	Silk screen	HA white prototype	x	x		x

Note: • All Finnish Plywood edges and corners rounded; all edges received four coats (4 ± ½ mil) Benjamin Moore Co. polysilicone enamel (brown); two coats before sheeting application, two coats after. Backs are dark brown unpainted.
• Silk screen ink, Advance Co. opaque black on 3C3.
• Silk screen ink, Advance Co. transparent red on 3C6.
• Silk screen KC Co., transparent black on 3C4.
• Silk screen KC Co., transparent red on 3C5.
• All faces lightly sanded.
• Only one of each installed at each test site per Avery International request.

[1]HA = heat-activated;
1200 = heat-activated, engineering-grade white;
1207 = heat-activated, engineering-grade green.

[2]Avery #900 vinyl film, top edge only.

[3]Advance Co. transparent clear coat;
KC Co. transparent clear coat.

Table 22.—*Reflective signs of Avery Int'l. materials placed at test sites, 1979*

Sign No.	Reflective Materials		Substrate	
	Legend[1]	Sheeting[1]	HDO plywood	Aluminum
11A1	Silk screen	1100	x	
11A2	3279	1100		x
11A3	Silk screen	1200		x
11A4	2279	1200	x	
11A5	Silk screen	1500	x	
11A6	3279	1500		x
11A7	Silk screen	1600		x
11A8	2279	1600	x	

Note: • All signs double cycled through heat vacuum applicator.
• All have Scotchcal brand transparent film (#639) placed along top edge for added protection against delamination.
• All have Advance Co. clear coating.

[1]1100 = engineering-grade, pressure-sensitive white;
1200 = engineering-grade, heat-activated white;
1500 = engineering-grade, pressure-sensitive white;
1600 = engineering-grade, heat-activated white;
2279 = 3M Co. engineering-grade, heat-activated brown;
3279 = 3M Co. engineering-grade, pressure-sensitive brown
3M Co. brown silk screen ink, 11A3;
Advance Co. Rex brown silk-screen ink, 11A1, 11A5, 11A7

Table 23.—*Reflective signs of Avery Int'l. materials placed at test sites, 1980*

Sign No.	Reflective Materials		Heat Application	
	Legend[1]	Sheeting[1]	Normal cycle	Double cycle
12A1	PS orange	1500	x	
12A2	HA orange	1600		x
12A3	PS orange	prismatic		

Note: • Sign 12A3 not cycled through heat applicator.
• All substrates HDO plywood.
• All have Scotchcal brand transparent film (#639) placed along top edge for added protection against delamination.

[1]1500 = engineering-grade, pressure-sensitive white;
1600 = engineering-grade, heat-activated prismatic reflective sheeting.

Table 24.—*Reflective signs of Avery Int'l. materials placed at test sites, 1981*

Sign No.	Reflective Materials		Substrate
	Legend	Sheeting	HDO plywood
13A1	HA vinyl	HA brown	x
13A2	HA vinyl	HA green	x
13A3	HA vinyl	HA orange	x
13A4		SGR white	GE lexan

Note: • All signs have Scotchcal brand transparent film (#639) placed along top edge for added protection against delamination.
• All signs double cycled through heat vacuum applicator except 13A4, which received no heat application.

Test Results

After almost 5 years of exposure the 6A series generally produced good results at the Hopewell Lake, N. Mex., test site. Exceptions included signs 6A1 and 6A2. These signs showed peeling of the legend. Sign 6A3 showed delamination and legend peeling at the other sites.

The 7A series showed combinations of severe delaminations of legend and sheeting at all sites. Exceptions included 7A5 and 7A6, two signs that performed well at all sites.

The 8A series produced mixed results at all test sites. Signs 8A3, 8A5, 8A6, 8A11, and 8A12 showed no failures at all sites. Other 8A signs produced combinations of peeling and delamination of legend and background sheeting.

The 9A series showed peeling and delamination of legend and sheeting at most test sites. Exceptions included signs 9A5, 9A10, 9A11, and 9A12. 9A series signs all used MDO plywood as the substrate, which may account for the excessive failure rate.

The 10A series showed peeling and delamination of legend and sheeting at all sites. 10A signs used Avery top edge protective film, which failed on all signs.

The 3C series, using Finnish plywood as the substrate, showed severe delamination at all but one test site. Animal damage at all test sites hindered evaluation of the 3C series.

The 11A series tested well at all test sites. 11A signs showed only slight peeling of the top edge treatment films at all sites.

The 12A series showed slight peeling of top edge treatment, and slight peeling of the sheeting at all sites.

The 13A series showed slight bending of the Lexan substrate, but no other failures.

Reflectivity became part of the test sign evaluation procedure in 1982. Reflectivity readings were taken randomly by Forest Service and industry personnel at each test site. Several readings of each color of reflective sheeting were taken, including those with silk-screened inks. All readings for a given type of sheeting were then averaged. Reflective sheeting materials all registered well above the FP 79 minimum standard except an engineering-grade silk-screened red that was installed in 1978 (table 25).

Discussion

The tests indicate that MDO plywood substrate often delaminates and causes reflective sheeting to fail. Finnish plywood is very durable, but because it is attractive to rodents, signs with Finnish plywood substrate sustained damage at all test sites.

Avery's top edge tapes have been ineffective, and may actually have caused reflective sheeting to peel on some signs. 3M's #639 top edge protective film worked well with Avery's reflective sheeting.

The clear coatings used on silk-screened legends tested well. Two different coatings, one from the Advance Co. and one from the K.C. Co., covered all silk-screened legends.

The most successful Avery signs used different combinations of these sign materials:

- HDO plywood substrate.

- Pressure-sensitive or heat-activated adhesive on reflective sheeting. Both types worked well when cycled through the heat vacuum applicator, once or twice, respectively.

- 3M Co. #639 top edge protective film on top edges.

- Clear coating on silk-screened applications.

To reduce costs, all signs manufactured since 1978 received two coats of polysilicone edge paint instead of four coats. This modification has not affected sign durability.

Conclusions

1. Specific combinations of substrates, reflective sheeting, top edge treatments, application techniques, and clear coatings will increase the service life of reflective signs.

Table 25.—*Average reflectivity readings for Avery Int'l. products, October 1982*

	Candelas/ft candle/sq ft	FP 79 standard[1] (candelas/ft candle/sq ft)
Installed — 1978		
Engineering-grade white	99.8	70.0
Engineering-grade green	15.6	9.0
Engineering-grade red (silk screened)	5.2	14.5
Installed — 1979		
Engineering-grade white	90.25	70.0
Engineering-grade brown (silk screened)	4.1	1.0
Installed — 1980		
Engineering-grade white	120.5	70.0
Prismatic white	392.4	250.0
Installed — 1981		
Engineering-grade white	91.3	70.0
Engineering-grade orange	27.6	25.0
Engineering-grade green	26.0	9.0
Engineering-grade brown	7.0	1.0

Note: Readings were taken by Forest Service and industry personnel using a retroreflectometer, Model 910, manufactured by the Gamma Scientific Co. This instrument includes an annular ring, factory installed and calibrated on September 15, 1981.

[1]These minimums are for new products; we have not established a minimum reflectivity for replacement sheeting. FP 79 is the national standard specification for road and bridge construction.

2. Medium Density Overlay (MDO) plywood should not be used as sign substrate material. MDO plywood is attractive to rodents and susceptible to delamination and to moisture collecting between the substrate and reflective sheeting.

3. Finnish plywood should not be used as sign substrate material. Although Finnish plywood is durable, it is very attractive to rodents. Test results showed this problem with Finnish plywood at every test site.

4. ABS plastic should not be used as substrate material for signs with expected long lives. ABS plastic signs showed failures in reflective sheeting and legends because they often bent and sometimes broke.

5. At the time of this evaluation, six signs with aluminum substrates, using both pressure-sensitive and heat-activated adhesive sheeting, have had 2 to 3 years of exposure. These signs all include Avery edge tape to protect top edges. Pressure-sensitive sheeting has been single cycled through a heat vacuum applicator; heat-activated sheeting has been double cycled through the heat vacuum applicator.

6. The best combinations of sign materials include HDO plywood substrates, reflective sheeting with heat-activated, double-cycled adhesive or pressure-sensitive single-cycled adhesive, and 3M Co. top edge protective tape. Clear coatings made by the Advance Co. and K.C. Co. tested well to protect silk-screened legends.

7. 3M Co.'s #639 top protective film should be used to treat top edges of all signs.

8. To further reduce costs, two coats of polysilicone paint on HDO plywood effectively replace four coats to protect sign edges.

Recommendations

The recommendations that follow are based on up to 4 years of outdoor testing. Manufacturing and maintenance costs were considered during testing and are reflected in the recommendations. For example, black HDO, which is impervious to moisture is recommended, reducing maintenance costs; the optional use of group 1 B grade veneers on both sides of the substrate, instead of exterior-marine grade, to lower cost; and the elimination of a special primer for the edge paint.

1. It is recommended that outdoor reflective signs for Forest Service use be manufactured with these combinations of materials and processes (they are recommended equally, and their order of presentation has no significance):

Reflective Sign of Aluminum

Substrate: No. 6061-T6 plate stock conforming to ASTM Standard B209.

Background Sheeting: Avery International engineering-grade brown with heat-activated adhesives.

Legend: Avery International engineering-grade silver with heat-activated or pressure-sensitive adhesive, or silk screened.

Manufacturing Process: (1) Double cycle through heat vacuum applicator. (2) Clear coat silk-screened legend per sheeting manufacturer's recommendations.

Top Edge Treatment: Apply 3M Co.'s Scotchcal transparent film (#639) over top edge of sign. For adequate protection, 3-inch-wide film is recommended. For ease of handling and cleanliness, it should be applied in 24-inch-long strips. On larger signs, begin taping from each outside edge and tape toward center of sign. Film should overlap at the center of sign 2 or more inches. The purpose of the film is to provide complete protection to the top edge of the sign to help prevent the sheeting from peeling from the substrate.

Reflective Sign of HDO Plywood and Engineering-Grade Sheeting

Substrate: HDO front and back. All Douglas-fir, exterior-marine grade, conforming to product standard PSI-74; or all Dougals-fir exterior plywood, PSI-74, group 1, with B grade veneers on both sides. HDO must be a 60-60 nonoiled resin impregnated fiber, black in color. Each panel should be edge-branded, marine-grade HDO EXT PSI-74 or HDO B-B G 1 EXT PS 1-74, 5-ply, ½-inch; or 7-ply, ¾-inch. (Thickness will vary depending on sign size, as defined in the Forest Service procurement and manufacturing specification.)

Background Sheeting: Avery International engineering-grade brown with heat-activated adhesives.

Legend: Avery International engineering-grade silver with heat-activated adhesives; or engineering-grade silver with pressure-sensitive adhesives; or silk-screened.

Manufacturing Process: (1) Cut plywood blank. (2) Round or bevel edges to a radius of 3/32 inch; round corners. (3) Finish-sand all edges and the panel face (HDO). (4) Clean all surfaces with a tack rag. (5) Before sheeting, apply one coat of Benjamin Moore Co.'s #120-60 polysilicone enamel as a primer to all edges. (6) Apply sheeting to substrate. (7) Apply one more coat of enamel to edges after sheeting has been applied to substrate. (8) Apply legend. If using heat-activated letters, cycle sign twice through the heat vacuum applicator. Do not apply clears. If using pressure-sensitive letters, cycle sheeting through heat vacuum applicator once before applying legend and once after. Do not apply clears.

Top Edge Treatment: Apply 3M Co.'s Scotchcal transparent film (#639) over top edge of sign. For adequate protection of ¾-inch plywood, 3-inch-wide film is recommended. For ease of handling and cleanliness, apply in 24-inch-long strips. On larger signs, begin taping from each outside edge and tape toward center of sign. Film should overlap at the center of the sign at least 2 inches. The purpose of the film is to provide complete protection to the top edge of the sign to help prevent the sheeting from peeling from the substrate.

2. Outdoor testing and evaluation of new sign combinations under cooperative agreements with reflective sheeting manufacturers should continue until project goals are met and to insure that the most desirable combinations for outdoor use are identified as the state-of-the-art advances.

Test Materials

Mitsubishi/Seibu International concluded a cooperative test agreement with the Forest Service in 1976. A test plan identical to the one agreed to by 3M was adopted and test plots established.

MEDC and Mitsubishi/Seibu International representatives selected 42 sign combinations (1B-6B series) for testing (tables 26-31). These were manufactured by Ojo Caliente Craftsmen Cooperative under the supervision of MEDC and company personnel. Substrates included HDO and MDO plywood, aluminum, and ABS plastic. Heat-activated and pressure-sensitive, engineering-grade brown and silver reflective sheeting underwent testing. "E," "O," and "N" were chosen to simulate the legend; in addition to the precut letters of reflective sheeting, some letters were silk screened. The edges of most plywood signs were painted with four coats of Benjamin Moore Co.'s polysilicone brown enamel; the edges of three signs were left unpainted and treated with a clear edge seal. In addition, the top edges of two plywood sign combinations were taped with Scotchcal transparent film (#639). Some signs were treated with clear coating; others were not, to verify if adhesives were durable without the added protection.

Some 252 test samples were installed at the three sites in November 1976 (84 signs per site) (fig. 12). The first evaluation took place in June 1977. After one winter of outdoor exposure, we found that some of the sheeting was peeling from the ABS substrate. In the evaluation in 1978 peeling continued on the ABS plastic.

In the fall of 1977 Mitsubishi/Seibu requested the manufacture and installation of three more sign combinations (18 test signs) (table 32). These signs (7B series) were installed at Hopewell Lake and Donner Summit in October 1977 and at Mount Adams in spring 1978. Combinations using Finnish plywood (1C series) were installed in 1978 (table 33).

During the fall of 1981 additional signs (8B series) were installed at the three test sites (table 34). They tested the durability and reflectivity of Seibu engineering-grade and new super engineering-grade (SEG) reflective sheeting manufactured in 1981.

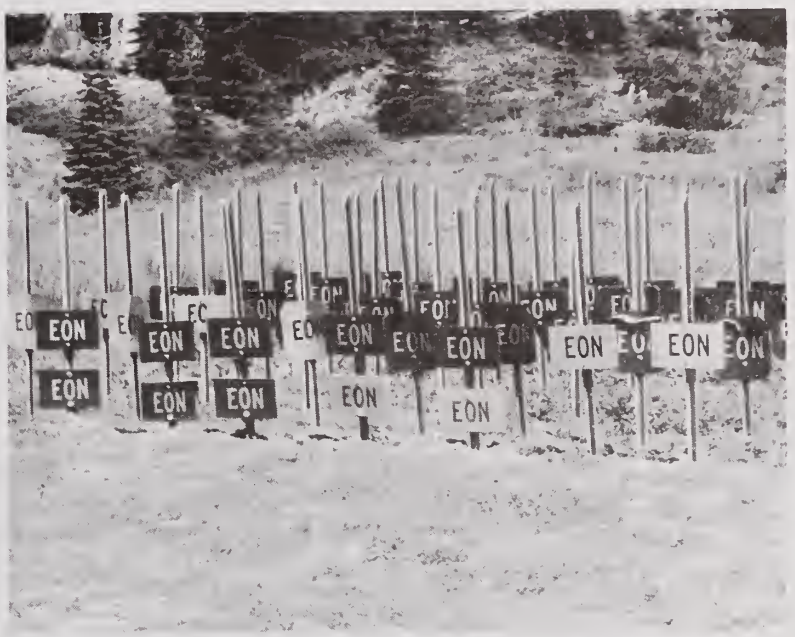

Figure 12.—Signs of Mitsubishi/Seibu International materials after 2 years of outdoor exposure.

Table 26.—*Reflective signs of Mitsubishi/Seibu Int'l. materials on aluminum substrate, placed at test sites, 1976*

Sign No.	Reflective Materials		Clear Coating (#3000)[2]	Heat Applicator	
	Legend[1]	Sheeting[1]	Complete face	Normal cycle	Double cycle
1B1	7102	7109			x
1B2	8102	7109			x
1B3	8102	8109		x	
1B4	7102	8109			x
1B5	Silk screen	8102		x	
1B6	Silk screen	7102	x	x	
1B7	7102	7109	x		x
1B8	7102	8109	x		x

Note: • Numbers refer to Mitsubishi/Seibu Int'l. product numbers.
• All sign edges squared.
• Silk screen ink: Seibulite #3015 Stop Sign Red (1B5); Seibulite #3003 Black (1B6).

[1]7102 = heat-activated, engineering-grade silver;
7109 = heat-activated, engineering-grade brown;
8102 = pressure-sensitive, engineering-grade silver;
8109 = pressure-sensitive, engineering-grade brown.

[2]#3000 clear is a special product for protecting sign face and legend.

Table 27.—*Reflective signs of Mitsubishi/Seibu Int'l. materials on HDO plywood substrate, placed at test sites, 1976*

Sign No.	Reflective Materials		Edge Treatment		Clear Coating	Heat Applicator	
	Legend[1]	Sheeting[1]	Corners and edges rounded	Corners and edges square	#3000[2] Face and legend	Normal cycle	Double cycle
2B1	7102	7109	x				x
2B2	8102	7109		x			x
2B3	8102	8109	x			x	
2B4	7102	8109		x			x
2B5	Silk screen	8102	x			x	
2B6	Silk screen	7102		x		x	
2B7	7102	7109	x		x		x
2B8	7102	8109		x	x		x

Note: • Numbers refer to Mitsubishi/Seibu Int'l. product numbers, unless otherwise indicated.
• All edges received four coats (4 ± ½ mil) of Benjamin Moore Co.'s polysilicone enamel (brown).
• Backs are black HDO unpainted.
• Silk screen ink: Seibulite #3015 Stop Sign Red (2B5);
Seibulite #3003 Black (2B6).

[1]7102 = heat-activated, engineering-grade silver;
7109 = heat-activated, engineering-grade brown;
8102 = pressure-sensitive, engineering-grade silver;
8109 = pressure-sensitive, engineering-grade brown.

[2]Seibulite #3000 clear is a special product for protecting the sign face and legend.

Table 28.—*Reflective signs of Mitsubishi/Seibu Int'l. materials on MDO plywood substrate, placed at test sites, 1976*

Sign No.	Reflective Materials		Edge Treatment		Clear Coating	Heat Applicator	
	Legend[1]	Sheeting[1]	Corners and edges rounded	Corners and edges square	#3000[2] Face and legend	Normal cycle	Double cycle
3B1	7102	7109	x				x
3B2	8102	7109		x			x
3B3	8102	8109	x			x	
3B4	7102	8109		x			x
3B5	Silk screen	8102	x			x	
3B6	Silk screen	7102		x		x	
3B7	7102	7109	x		x		x
3B8	7102	8109		x	x		x

Note: • Numbers refer to Mitsubishi/Seibu Int'l. product numbers.
• All edges and backs received four coats (4 ± ½ mil) of Benjamin Moore Co.'s polysilicone enamel (brown).
• Backs painted before sheeting applied.
• Silk screen ink: Seibulite #3015 Stop Sign Red (3B5);
Seibulite #3003 Black (3B6).

[1]7102 = heat-activated, engineering-grade silver;
7109 = heat-activated, engineering-grade brown;
8102 = pressure-sensitive, engineering-grade silver;
8109 = pressure-sensitive, engineering-grade brown.

[2]#3000 clear is a special product for protecting sign face and legend.

Table 29.— *Reflective signs of Mitsubishi/Seibu Int'l. materials on ABS "accurene" brown plastic, placed at test sites, 1976*

Sign No.	Reflective Materials		Clear Coating (#3000)[2]	Heat Applicator	
	Legend[1]	Sheeting[1]	Complete face	Normal cycle	Double cycle
4B1	7102	7109			x
4B2	8102	7109			x
4B3	8102	8109		x	
4B4	7102	8109			x
4B5	Silk screen	8102		x	
4B6	Silk screen	7102		x	
4B7	7102	7109	x		x
4B8	7102	8109	x		x

Note: • Numbers refer to Mitsubishi/Seibu Int'l. product numbers.
• All sign corners rounded.
• Silk screen ink: Seibulite #3015 Stop Sign Red (4B5); Seibulite #3003 Black (4B6).

[1]7102 = heat-activated, engineering-grade silver;
7109 = heat-activated, engineering-grade brown;
8102 = pressure-sensitive, engineering-grade silver;
8109 = pressure-sensitive, engineering-grade brown.

[2]#3000 clear is a special product for protecting sign face and legend.

Table 31.— *Reflective signs of Mitsubishi/Seibu Int'l. materials on HDO plywood substrate, placed at test sites, 1976*

Sign No.	Reflective Materials		Clear Coating (#3000)[2]	Heat Applicator	
	Legend[1]	Sheeting[1]	Face & legend	Normal cycle	Double cycle
6B1	3M Co. 2270	7109			x
6B2	3M Co. 3270	7109			x
6B3	7102	3M Co. 3279		x	
6B4	7102	3M Co. 3279			x
6B5	Silk screen	8102		x	
6B6	Silk screen	3M Co. 2270		x	
6B7	3M Co. 3270	7109	x	x	
6B8	7102	3M Co. 2279	x		x

Note: All edges and corners square no paint.

[1]7102 = heat-activated, engineering-grade silver;
7109 = heat-activated, engineering-grade brown;
8102 = pressure-sensitive, engineering-grade brown;
3M 2270 = heat-activated, engineering-grade silver;
3M 3270 = pressure-sensitive, engineering-grade silver;
3M 2279 = heat-activated, engineering-grade brown;
3M 3279 = pressure-sensitive, engineering-grade brown.

[2]#3000 clear is a special product for protecting sign face and legend.

Table 30.—*Reflective signs of Mitsubishi/Seibu Int'l. materials on HDO plywood substrate, placed at test sites, 1976*

Sign No.	Reflective Materials		Edge Treatment		Heat Applicator	
	Legend[1]	Sheeting[1]	Corners and edges rounded	#639 film[2]	Normal cycle	Double cycle
5B1	7102	8109	x	x	x	
5B2	7102	7109	x	x		x

Note: • All edges received four coats (4½ ± ½ mil) of Benjamin Moore Co. polysilicone enamel (brown) — two coats before sheeting applicaiton, two coats after; backs are black HDO unpainted.

[1]7102 heat-activated, engineering-grade silver;
7109 heat-activated, engineering-grade brown;
8109 pressure-sensitive, engineering-grade brown.

[2]3M Co. Scotchcal brand transparent film (#639) placed on top edge only.

Table 32.—*Reflective signs of Mitsubishi/Seibu Int'l. materials on HDO plywood substrates, placed at Hopewell Lake and Donner Summit, 1977, Mount Adams, 1978*

Sign No.	Reflective Materials		Edge Treatment	Clear Coating	Heat Applicator	
	Legend[1]	Sheeting[1]	WSAS[2]	#3000 Face & Legend[3]	Normal cycle	Double cycle
7B1	8102	7109			x	
7B2	7102	7109	x	1 coat		x
7B3	7109	7112	x	2 coats		x

Note: • Numbers refer to Mitsubishi/Seibu Int'l. product numbers.
• All sign edges square and unpainted.
• Backs are black HDO unpainted.

[1]7102 = heat-activated, engineering-grade silver;
7112 = heat-activated, engineering-grade white-white;
7109 = heat-activated, engineering-grade brown;
8102 = pressure-sensitive, engineering-grade silver.

[2]WSAS water soluble acrylic sealant used to seal sign edges.

[3]#3000 clear is a special product for protecting sign face and legend.

Table 33.—*Reflective signs of Mitsubishi/Seibu Int'l. materials on Finnish plywood substrate (phenolic resin film overlay), placed at test sites, 1977*

Sign No.	Reflective Materials		Heat Application	
	Legend[1]	Sheeting[1]	Normal cycle	Double cycle
1C1	7102	7109	x	
1C2	7102	7109		x
1C3	8102	7109		x

Note: • All faces lightly sanded.
• No edge treatments per request from Finnish Plywood Association U.S.A.

[1]7102 = heat-activated, engineering-grade, silver;
7109 = heat-activated, engineering-grade brown;
8102 = pressure-sensitive, engineering-grade silver.

Table 34.—*Reflective signs of Mitsubishi/Seibu Int'l. materials placed at test sites, 1981*

Sign No.	Reflective Materials[1]		Substrate	
	Legend	Sheeting	HDO plywood	Aluminum
8B1	Silk screen	8112	x	
8B2	Silk screen	7112		x
8B3	3207	7109		x
8B4	Silk screen	18112		x
8B5	3870	17108	x	
8B6	18112	18004	x	

Note: • No top edge treatments or clearcoat on any signs.
• 8B2, 8B3, 8B5 double cycled through heat vacuum applicator; 8B1, 8B4, 8B6, not cycled through.
• Silk screen inks used: Seibulite 3509 brown on 8B1, 3M Co. 712 stop sign red on 8B2; Seibulite 3515 traffic sign red on 8B4.

[1]3207 = 3M Co. engineering-grade, pressure-sensitive white;
3870 = 3M Co. high-intensity, pressure-sensitive silver white;
7109 = Seibulite engineering-grade, heat-activated brown;
7112 = Seibulite engineering-grade, heat-activated white;
8112 = Seibulite engineering-grade, pressure-sensitive white;
17108 = Seibulite super engineering-grade, heat-activated green;
18004 = Seibulite super engineering-grade, pressure-sensitive yellow;
18112 = Seibulite super engineering-grade, pressure-sensitive white.

Test Results

The 1B series, after 5 years of exposure, showed no legend peeling, but most background sheeting was peeling from these aluminum signs. Exceptions included 1B3, 1B4, 1B5, and 1B8.

The 2B series signs used an HDO plywood substrate. These signs showed legend peeling on only one sign, 2B3, and slight peeling on the top edge of the sheeting on one sign, 2B4. All other 2B series signs performed without failures.

The 3B series signs used an MDO plywood substrate. These signs showed extensive delamination and sustained severe animal damage.

The 4B series signs used an ABS plastic substrate. These signs showed delamination and peeling, because the plastic often bent and sometimes broke.

The 5B series signs used an HDO plywood substrate. Sign 5B1 showed delamination and peeling on the top edge and sheeting. Sign 5B2 performed well. This latter sign was double cycled through the heat vacuum applicator.

The 6B series used an HDO plywood substrate. Sign 6B8 showed delamination and peeling of both sheeting and legend. Signs 6B1, 6B2, and 6B7 all showed delamination and peeling of sign legend only.

The 7B series used HDO plywood as a substrate; 7B signs all showed delamination and peeling of both sheeting and legend.

The 8B series signs show some failure after 1 year of exposure. 8B1, 2, and 4 have slight peel on the top edge of the sheeting; 8B3 and 6 have severe peel on legends. At the time of this report, 8B series signs had not been in place long enough to obtain a full evaluation.

Finnish plywood (1C series) proved durable, but quite attractive to animals.

Reflectivity became part of the test sign evaluation procedure in 1982. Reflectivity readings were taken randomly by Forest Service and industry personnel at each test site. Several readings of each color of reflective sheeting were taken, including those with silk-screened inks. All readings for a given type of sheeting were then averaged. Reflective sheeting materials all registered well above the FP 79 minimum (table 35).

Discussion

The tests indicate that signs made of Seibulite reflective materials have met the Forest Service's expectations for maintenance free signs. The Forest Service expects signs to remain maintenance free for 7 years. MDO plywood suffered extensive animal damage and frequent delamination and ABS plastic signs bent and broke often during the tests. Both of these substrates allowed delamination and peeling of sign legends and sheeting. Finnish plywood is very durable, but consistently severe damage from animals makes Finnish plywood unacceptable for Forest Service signs.

7B series signs that were installed in 1978 showed good performances from signs that were double cycled through the heat vacuum applicator and that used Seibu (WAS) edge seal.

Although 8B series signs were recently placed, they have begun to show minor failures. After 1 year, all 8B signs except 8B5 have shown slight cracking and peeling.

To reduce costs, we have lowered the number of plywood edge coatings from four to two. Two coats of polysilicone enamel instead of four have not lessened sign durability.

Conclusions

1. Specific combinations of substrates, reflective sheeting, top edge treatments, application techniques, and clear coatings will increase the service life of reflective signs.

2. Medium Density Overlay (MDO) plywood should not be used as sign substrate material. MDO plywood is attractive to rodents and susceptible to delamination because moisture collects between the substrate and reflective sheeting.

3. Finnish plywood should not be used as sign substrate material. Although Finnish plywood is durable, it is very attractive to rodents. Test results showed this problem with Finnish plywood at every test site.

Table 35.—*Average reflectivity readings for Seibu International products, October 1982*

	Candelas/ft candle/sq ft	FP 79 standard[1] (candelas/ft candle/sq ft)
Installed — 1976		
Engineering-grade brown	8.2	1.0
Engineering-grade red (silk screen)	23.7	14.5
Engineering-grade black (silk screen)	44.6	0.0
Engineering-grade white	112.4	70.0
Installed — 1978		
Engineering-grade brown	12.0	1.0
Engineering-grade white	125.6	70.0
Installed — 1981		
Engineering-grade brown	10.0	1.0
Engineering-grade white	83.0	70.0
Super engineering-grade green	43.5	26.0
Super engineering-grade yellow	123.5	—[2]
Super engineering-grade white	149.25	—[2]
Engineering-grade Seibulite brown	17.25	—[2]
Super engineering-grade red (silk screened; traffic sign)	26.5	—[2]

Note: Readings were taken by Forest Service and industry personnel using a retroreflectometer, Model 910, manufactured by the Gamma Scientific Co. This instrument includes an annular ring, factory installed and calibrated on September 15, 1981.

[1]These minimums are for new products; we have not established a minimum reflectivity for replacement sheeting. FP 79 is the national standard specification for road and bridge construction.

[2]No standard has been established.

4. ABS plastic should not be used as substrate material for signs with expected long lives. ABS plastic signs showed failures in reflective sheeting and legends because substrates often bent and sometimes broke.

5. Aluminum substrates worked well with Seibulite engineering-grade, pressure-sensitive adhesive that was single cycled through the heat vacuum applicator.

6. Most successful combinations of sign materials included Seibulite engineering-grade reflective letters, numerals, symbols, and silk-screened inks. These materials worked well on backgrounds of Seibulite reflective sheeting.

7. High Density Overlay (HDO) plywood proved to be the best substrate material.

8. The benefits of using Seibu #3000 clear coating as a top edge treatment have not been established. Tests showed as many failures using this coating as successes.

9. Seibu #3000 clear coating increased its effectiveness when used with 3M Co.'s #639 top edge treatment film.

10. 8B series signs should be checked frequently to monitor early indications of delamination and peeling.

11. To reduce costs, two coats of polysilicone paint on HDO plywood effectively replace four coats to protect sign edges.

Recommendations

The recommendations that follow are based on up to 6 years of outdoor testing. Manufacturing and maintenance costs were considered during testing and are reflected in the recommendations. For example, black HDO, which is impervious to moisture, is recommended, reducing maintenance costs; the optional use of group 1 B grade veneers on both sides of the substrate, instead of exterior-marine grade, to lower costs; and the elimination of a special primer for the edge paint.

1. It is recommended that outdoor reflective signs for Forest Service use be manufactured with these combinations of materials and processes (they are recommended equally, and their order of presentation has no significance):

Reflective Sign of Aluminum

Substrate: No. 6061-T6 plate stock conforming to ASTM Standard B209.

Background Sheeting: Seibu International's engineering-grade brown with pressure-sensitive adhesives (#8109).

Legend: Seibu International's engineering-grade white with heat-activated adhesive (#8102) or pressure-sensitive adhesive (#7102) or silk screened.

Manufacturing Process: (1) Double cycle through heat vacuum applicator. (2) Clear coat silk-screened legend per sheeting manufacturer's recommendations.

Top Edge Treatment: Apply 3M Co.'s Scotchcal transparent film (#639) over top edge of sign. For adequate protection, 3-inch-wide film is recommended. For ease of handling and cleanliness, it should be applied in 24-inch-long strips. On larger signs, begin taping from each outside edge and tape toward center of sign. Film should overlap at the center of sign 2 or more inches. The purpose of the film is to provide complete protection to the top edge of the sign to help prevent the sheeting from peeling from the substrate.

Reflective Sign of HDO Plywood and Engineering-Grade Sheeting

Substrate: HDO front and back. All Douglas-fir, exterior-marine grade, conforming to product standard PSI-74; or all Douglas-fir exterior plywood, PSI-74, group 1, with B grade veneers on both sides. HDO must be a 60-60 nonoiled resin impregnated fiber, black in color. Each panel should be edge-branded, marine-grade HDO EXT PSI-74 or HDO B-B G1 EXT PS 1-74, 5-ply, ½-inch; or 7-ply, ¾-inch. (Thickness will vary depending on sign size, as defined in the Forest Service procurement and manufacturing specification.)

Background Sheeting: Seibu International's engineering-grade with heat-activated or pressure-sensitive adhesives.

Legend: Seibu International engineering-grade with heat-activated adhesives; or Seibulite engineering-grade with pressure-sensitive adhesives; or silk-screened.

Manufacturing Process: (1) Cut plywood blank. (2) Round or bevel edges to a radius of 3/32 inch; round corners. (3) Finish-sand all edges and the panel face (HDO). (4) Clean all surfaces with a tack rag. (5) Before sheeting, apply one coat of Benjamin Moore Co.'s #120-60 polysilicone enamel as a primer to all edges. (6) Apply sheeting to substrate. (7) Apply one more coat of enamel to edges after sheeting has been applied to substrate. (8) Apply legend. If using heat-activated letters, cycle sign twice through the heat vacuum applicator. Do not apply clears. If using pressure-sensitive letters, cycle sheeting through heat vacuum applicator once before applying legend and once after. Do not apply clears unless specifically recommended by the manufacturer.

Top Edge Treatment: Apply 3M Co.'s Scotchcal transparent film (#639) over top edge of sign. For adequate protection of ¾-inch plywood, 3-inch-wide film is recommended. For ease of handling and cleanliness, apply in 24-inch-long strips. On larger signs, begin taping from each outside edge and tape toward center of sign. Film should overlap at the center of the sign at least 2 inches. The purpose of the film is to provide complete protection to the top edge of the sign to help prevent the sheeting from peeling from the substrate.

2. Outdoor testing and evaluation of new sign combinations under cooperative agreements with reflective sheeting manufacturers should continue until project goals are met and to insure that the most desirable combinations for outdoor use are identified as the state-of-the-art advances.

Test Materials

In 1979 the Reflexite Corp. asked to join the Forest Service tests. A cooperative test agreement and test plan were concluded. These were identical to the ones drawn up with 3M Co., Avery International, and Mitsubishi/Seibu International.

Twenty-three combinations of sign materials (1R1-23 series) were produced from Reflexite products by Ojo Caliente Craftsmen, Ojo Calienti, N. Mex. (table 36). Reflexite and MEDC supervised sign manufacture.

The signs used substrates of HDO plywood, aluminum, and fabric (six rollup signs of polyvinyl chloride on fabric were included in the test combinations) (figs. 13, 14); two roll up signs used a plywood substrate. Reflective sheeting materials were polyvinyl chloride in orange and orange and white and polycarbonate in white, yellow, red, green, and brown. The "E," "O," and "N" of the legends were of three types: silk screened; 3M Co. heat-activated or pressure-sensitive Scotchlite; die cut pressure-sensitive polycarbonate acrylic. Some signs were manufactured using Reflexite's acrylic clear coating, which includes a water base and ultraviolet inhibitors.

Signs of aluminum and plywood measured 8 by 14 inches; the roll up fabric signs, 12 by 12 inches and 12 by 24 inches. Signs were installed 18 to 24 inches above ground on steel U-channel posts set in rows at the test plots. Signs faced south for maximum exposure to ultraviolet rays.

Table 36.—*Reflective signs of Reflexite Corp. placed at test sites, 1979*

Sign No.	Reflective Materials: Legend	Reflective Materials: Sheeting	Substrate	Adhesive	Clear Coating
1R1	Silk screened	Flexible PVC orange rollup	Fabric		None
1R2	Silk screened	Flexible PVC orange rollup	Fabric		UV-cured clear acrylic
1R3	None	Flexible PVC prestriped orange & white	HDO plywood	PS	None
1R4	None	Flexible PVC prestriped orange & white	HDO plywood	PS	UV-cured clear acrylic
1R5	None	Flexible PVC prestriped orange & white	Fabric		None
1R6	None	Flexible PVC prestriped orange & white	Fabric		UV-cured clear acrylic
1R7	None	Flexible PVC prestriped orange & white	Fabric		None
1R8	None	Flexible PVC prestriped orange & white	Fabric		UV-cured clear acrylic
1R9	Silk screened	Polycarbonate white	Aluminum	PS acrylic	None
1R10	Silk screened	Polycarbonate white	HDO plywood	PS acrylic	None
1R11	Silk screened	Polycarbonate white	Aluminum	PS acrylic	Water-based acrylic
1R12	Silk screened	Polycarbonate white	HDO plywood	PS acrylic	Water-based acrylic
1R13	Silk screened	Polycarbonate white	Aluminum	PS acrylic	UV-cured acrylic
1R14	Silk screened	Polycarbonate white	HDO plywood	PS acrylic	UV-cured acrylic
1R15	3M Co. HA black scotchlite	Polycarbonate yellow	HDO plywood	PS rubber	None
1R16	3M Co. PS black scotchlite	Polycarbonate yellow	Aluminum	PS rubber	None
1R17	3M Co. HA black scotchlite	Polycarbonate yellow	HDO plywood	PS rubber	Water-based acrylic
1R18	3M Co. PS black scotchlite	Polycarbonate yellow	Aluminum	PS rubber	Water-based acrylic
1R19	3M Co. HA black scotchlite	Polycarbonate yellow	HDO plywood	PS rubber	UV-cured acrylic
1R20	3M Co. PS black scotchlite	Polycarbonate yellow	Aluminum	PS rubber	UV-cured acrylic
1R21	die cut white polycarbonate acrylic PS	Polycarbonate red	HDO plywood	PS acrylic	None
1R22	die cut white acrylic PS	Polycarbonate green	HDO plywood	PS acrylic	UV-cured acrylic
1R23	die cut white acrylic PS	Polycarbonate brown	HDO plywood	PS acrylic	Water-based acrylic

Note: • Scotchcal brand transparent film (#639) placed along the top edge of all aluminum and HDO plywood signs for added protection against delamination.

• Silk screen ink used is Advance black HP on 1R1 and 1R2; Advance UV cured black on 1R9 through 1R14.

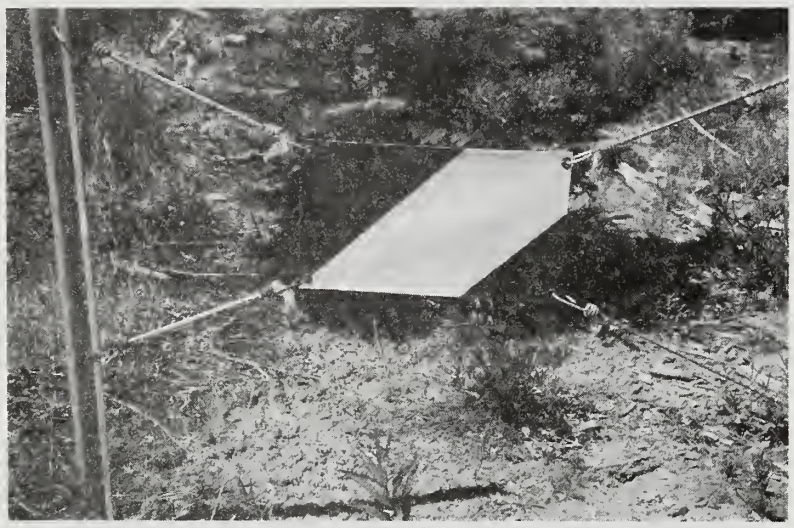

Figure 13.—Reflexite Corp.'s barricade material at test site.

Figure 14.—Reflexite Corp.'s roll-up sign at test site.

Some 69 test samples were installed at the three test sites in October 1979 (23 signs per site). In 1980 another four combinations (1R 24-27) were added (table 37). An additional five combinations (2R series) were installed at test plots in October 1981 (table 38).

Test Results

Reflexite test signs were evaluated in July 1982. The roll up and fabric signs 1R1, 1R2, and 1R5-8 showed no failures after 3 years of exposure. Signs 1R3 and 1R4 used roll-up fabric signs on HDO plywood, and sheeting of 1R4 was peeling. Signs 1R9 and 1R10 showed no failures. Signs 1R11-14, 1R16, 1R19, and 1R23 all showed some peeling of legends; sheeting was peeling from signs 1R15, 1R17, 1R18, and 1R20-22.

Table 37.—*Reflective signs of Reflexite Corp. placed at test site, 1980*

Sign No.	Reflective Materials		Substrate	
	Legend	Sheeting	HDO plywood	Aluminum
1R24	White PS acrylic	Polycarbonate green	x	
1R25	White PS acrylic	Polycarbonate green		x
1R26	White PS acrylic	Polycarbonate blue	x	
1R27	White PS acrylic	Polycarbonate blue		x

Note: Scotchcal brand transparent film (#639) placed along top edge of all signs for added protection against delamination.

Legends on signs 1R24-27 were delaminating and peeling after 2 years of exposure. Background sheeting resisted delamination and peeling in all these signs.

Series 2R1-5 signs showed no failures of legend or sheeting after 1 year of testing.

Reflectivity became part of the test sign evaluation procedure in 1982. Reflectivity readings were taken randomly by Forest Service and Reflexite personnel at each test site. Several readings of each color of reflective sheeting were taken including one with silk screened ink. All readings for a given type of sheeting were then averaged. Reflective sheeting materials all registered above the FP 79 minimum standard (table 39).

Table 38.— *Reflective signs of Reflexite Corp. materials placed at test sites, 1981*

Sign No.	Reflective Materials		Substrate	
	Legend	Sheeting	HDO plywood	Aluminum
2R1	Silk screen	Acrylic 1000 PS amber	x	
2R2	Acrylic 1000 PS white	Acrylic 1000 PS red		x
2R3	Silk screen	Acrylic 1000 PS white	x	
2R4	Acrylic 1000 PS white	Acrylic 1000 PS orange	x	
2R5	Acrylic 1000 PS white	Acrylic 1000 PS green	x	

Note: Scotchcal brand transparent film (#639) placed along top edge of all signs for added protection against delamination.

Discussion

The tests indicate that Reflexite roll-up and fabric signs performed well. These signs work well for temporary construction zones, barricades, and for emergency warnings. Although roll-up signs placed on substrates of either HDO plywood or aluminum all used 3M Co. Scotchcal #639 top edge treatment film, these signs showed many failures. Exceptions included signs 1R3, 1R4, 1R9, and 1R10. Series 1R24 through 1R27, signs that included pressure-sensitive acrylic legends, all showed legend peeling and delamination with no background sheeting failures. Series 2R1 through 2R5 signs all used acrylic 1000 legends from Reflexite. These signs showed no failures.

Conclusions

1. Reflexite roll-up and fabric signs meet the Forest Service's expectations for maintenance-free signs.

2. Other sign combinations tested have not been exposed long enough to warrant further specific conclusions.

Recommendations

Note: These recommendations are based on limited times of exposure during tests.

1. The Reflexite system of reflective signs works well where a job calls for highly reflective signs. Examples of good applications for Reflexite signs include highway construction and maintenance zones, traffic emergency zones, temporary barricades, and guardrail delineators. Reflexite's acrylic 1000 will work well with guardrail delineators.

2. At this time Reflexite's manufacturing procedures and specifications are adequate for Forest Service signs.

Table 39.—*Average reflectivity readings for Reflexite Corp. products, October 1982*

	Candelas/ft candle/sq ft	FP 79 standard[1] (candelas/ft candle/sq ft)
Installed — 1979		
White PVC	408.3	256.0
Orange PVC	71.0	70.0
White acrylic	786.0	250.0
Orange acrylic	122.6	70.0
White polycarbonate	866.3	250.0
Yellow polycarbonate	585.0	170.0
Black silk screen on white polycarbonate	90.0	0.0
Installed — 1980		
Green polycarbonate	151.3	30.0
Blue polycarbonate	74.0	20.0
Installed — 1981		
Amber acrylic 1000	470.0	—[2]
Red acrylic 1000	105.8	35.0
White acrylic 1000	672.6	250.0
Orange acrylic 1000	139.0	70.0
Green acrylic 1000	93.3	30.0

Note: Readings were taken by Forest Service and industry personnel using a retroreflectometer, Model 910, manufactured by the Gamma Scientific Co. This instrument includes an annular ring, factory installed and calibrated on September 15, 1981.

[1]These minimums are for new products; we have not established a minimum reflectivity for replacement sheeting. FP79 is the national standard specification for road and bridge construction.

[2]No standard has been established.

Part VI — Carsonite International

Test Materials

In 1976 Carsonite International, a manufacturer of flexible delineator posts asked to join the Forest Service tests. Materials installed at the test sites were minimal until 1979. In that year Carsonite began a more formal program of selecting and placing its products at the three test sites under a test plan similar to those drawn up between the Forest Service and 3M Co., Avery International, Mitsubishi/Seibu International, and Reflexite Corp.

Carsonite has installed several combinations of reflective sheeting from 3M, Avery, and Mitsubishi/Seibu, using its delineator post material as the substrate (fig. 15). Other combinations, using a variation of the post material with the same reflective sheeting, are also under test.

Figure 15.—Carsonite flexible delineator post with reflective sheeting installed in 1980.

Test Results

The 1976 flexible delineator posts showed a loss of resin, exposing the fiberglass fibers after 2 to 3 years of outdoor exposure. Also, the reflective sheeting was peeling and delaminating (fig. 16). The posts installed in 1979 showed slight fiber exposure, while the 1980 and 1982 series look excellent.

Figure 16.—Reflective sheeting peeling and delaminating from delineator posts after 3 years' exposure.

Discussion

Compatibility of flexible posts with reflective sheeting has not been established. Carsonite has added ultraviolet ray inhibitors, improved resin, and stabilizers to its post material. These combinations look excellent to date (1983).

Durability of reflective sheeting on the posts has not been sufficiently established at this time to recommend the use of any one specific reflective sheeting. It is recommended that 3M Co.'s Scotchcal brand transparent film #639 be used on the top edge, extending about 1 inch over the top (both sides) and at least ½ inch over reflective sheeting or top number or letter.

Test Materials

In the fall of 1978 two vandal-resistant hardware manufacturers requested permission to enter the test program. These were Voi-Shan Co., Culver City, Calif. (now Simi Fastening Systems, Simi Valley, Calif.), which produces Vandalgard hardware and the Tufnut Works, Santa Fe, N. Mex., manufacturer of Tufnut products.

Since 1978, all new signs have been installed with hardware from these companies (figs. 17, 18). Also, a program was begun to replace standard mounting nuts and bolts on signs installed before 1978 with vandal-resistant products.

Figure 17.—Vandalgard hardware from Voi-Shan Co.

Figure 18.—Vandal-resistant hardware from Tufnut Works.

Test Results

Before vandal-resistant hardware came into use at the outdoor test sites, some signs were taken from the Hopewell Lake, N. Mex., site. But since 1978, no signs have been removed by vandals. In the outdoor tests, the vandal-resistant hardware has proven to be durable and easy to use. It should be recommended for use with all Forest Service signs.

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